H_2S 4 hr END USER

Instructor Manual

PEC SAFETY

Title: Hydrogen Sulfide 4 Hour End User
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Disclaimer: Course participants will not have met the requirements to work in H_2S environments above the Occupational Exposure Limits (OEL) until such time as the company provides and documents additional applicable training required by 29 CFR, including medical evaluations, fit testing, and use of respirators and monitor and rescue equipment specific to the workplace.

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Instructor's Foreword

PEC Safety produces safety training materials relative to the oil and gas industry regulations as set forth by the Occupational Safety and Health Administration and other regulatory agencies. It is the goal of PEC Safety to provide current, comprehensive materials that promote a culture of safety and safety practices in the work and personal environments. While instructors may choose to supplement course materials with additional information, it is imperative that regulations outlined in PEC Safety course materials be covered in their entirety.

Course Goal

Upon course completion, students will gain the necessary knowledge to work safely in environments contaminated with hydrogen sulfide. This course is intended for oil and gas industry workers who may come in contact with hydrogen sulfide during their regular job duties.

Course Objectives

Upon course completion, students will be able to:

- Identify the hazards associated with hydrogen sulfide
- List the major properties of hydrogen sulfide
- Name common sources of hydrogen sulfide
- Discuss facility engineering controls
- Discuss safe workplace practices involving hydrogen sulfide
- Describe the importance of confined space entry procedures
- List hydrogen sulfide exposure limits and the personal protective equipment requirements for each limit
- Recognize symptoms of hydrogen sulfide exposure
- Recognize warning signals for hydrogen sulfide detection systems to be used
- Describe the correct use of monitoring equipment
- Give examples of proper rescue and first aid techniques for victims of hydrogen sulfide exposure
- Name the essential parts of a hydrogen sulfide contingency plan
- Explain the significance of wind direction indicators

Company Responsibilities

In addition to presenting PEC Safety's Hydrogen Sulfide End User course material, companies must complete the following tasks to be in compliance with OSHA's regulatory requirements:

- Verify that workers have completed a hydrogen sulfide training program before working at a facility
- Provide refresher hydrogen sulfide training for all workers annually
- Cover site-specific hydrogen sulfide training for individual facilities
- Implement a respiratory protection program that conforms to the OSHA Respiratory Protection standard, 29 CFR 1910.134
- Train workers in the required elements of 29 CFR 1910.134
- Make sure workers receive site-specific contingency plans specifying the quantity and location of available respiratory equipment
- Provide hands-on training to workers on the use company-provided self-contained breathing apparatuses, hydrogen sulfide gas detectors, and resuscitation equipment correctly in the field

Course Materials

- Copy of the company Contingency Plan (optional)
- Tests, SITAS, Answer Keys, and Supplemental Answer Sheets
- Hydrogen Sulfide End User Student Manual
- Hydrogen Sulfide End User Instructor Manual
- PowerPoint Presentation

Contents

HYDROGEN SULFIDE END USER

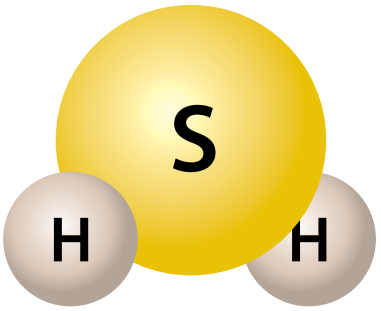
Introduction

Hydrogen sulfide, or H_2S, is a hazard that can creep up on you. You cannot see it, and if the concentration is high enough, you will not even be able to smell it. This toxic gas is colorless and collects in low-lying areas. H_2S is so powerful that it can kill you with one breath. It is known as "The Silent Killer." In this course, we will review how you can protect yourself and your coworkers from hazardous exposure to H_2S.

Regulations and Standards

Several government agencies regulate H_2S exposure. OSHA enforces safety regulations, lists exposure limits for the gas, and has specific respiratory protection requirements listed in 29 CFR 1910.134. The National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) provide exposure recommendations, and the American National Standards Institute (ANSI) provides specific practices to use to mitigate the hazards of H_2S within the oil and gas industry. The American Petroleum Institute (API) writes recommended practices for operations involving H_2S in the oil and gas industry.

The Environmental Protection Agency (EPA) formed two laws, the Superfund Amendments and Reauthorization Act (SARA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which specify the reportable quantities (RQs) for hazardous materials. H_2S has an RQ of 100 lbs., and sulfur dioxide (SO_2), a byproduct of H_2S combustion, has an RQ of 1 lb.



H_2S molecule

For more information, see the following list of standards that address H_2S:

- ANSI Z390.1-2006 (R2010): Accepted Practices for Hydrogen Sulfide (H_2S) Training Programs
- 29 CFR 1910.1000 Table 2
- API Recommended Practice 49: Recommended Practice for Drilling and Well Servicing Operations Involving Hydrogen Sulfide
- API Recommended Practice 55: Recommended Practices for Oil and Gas Production and Gas Processing Plant Operations Involving Hydrogen Sulfide
- Bureau of Safety and Environmental Enforcement (BSEE) 30 CFR 250.490: Hydrogen Sulfide
- Various state regulatory agencies, such as Texas Railroad Commission and the Oklahoma Corporation Commission
- US Coast Guard (USCG)
- Bureau of Land Management
- State OSHA Plans
- Environment Canada
- Workplace Hazardous Materials Information System (WHMIS)

In addition to the federal agencies, states also have their own regulations about H_2S. If you are not sure which regulations apply to you, consult your company representative and your state's code of law.

Responsibilities

Each person involved in a company's operations has certain responsibilities. Different responsibilities apply to companies and workers.

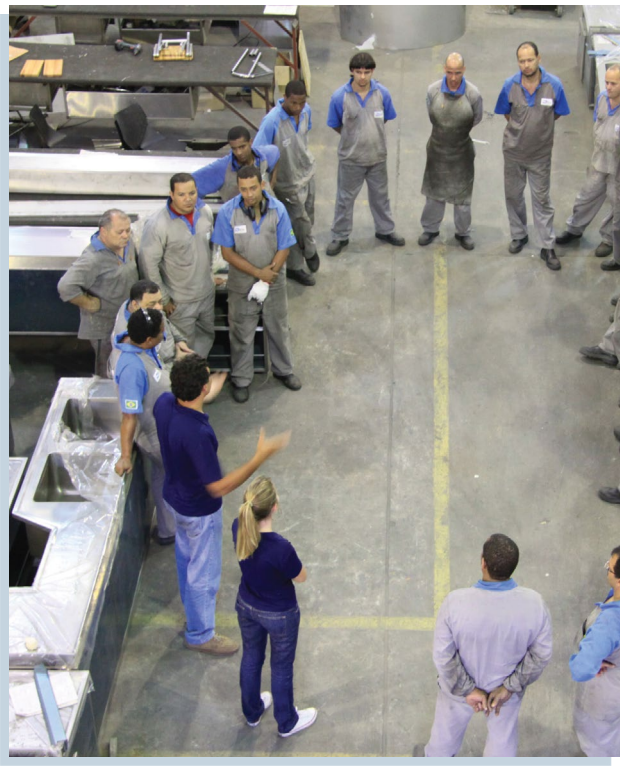
Responsibilities	
Company	**Worker**
- Protecting workers from H_2S exposure - Identifying H_2S hazards - Providing appropriate training to all workers - Establishing safe work practices relating to H_2S - Monitoring H_2S levels throughout the workplace - Providing PPE specifically designed to shield the workers from effects of H_2S - Developing contingency plans in the event of an accident/incident - Accounting for workers - Performing a thorough check for ignition sources in the area before starting any potentially hazardous work - Providing at least one worker qualified to perform first aid and CPR for H_2S victims - Establishing and enacting drilling fluid treatment plans before encountering H_2S	- Attending H_2S education and training sessions - Using controls and following safe work practices - Using required PPE and personal monitors - Reporting exposure incidents - Using SWA when necessary

Training

Companies are responsible for training workers in a way that every worker can understand. All workers must receive appropriate training according to their level of potential exposure to H_2S. Training should cover

- What to do in emergencies
- Your role in the H_2S contingency plan
- Participation in drills

Workers should participate in drills that simulate an emergency involving H_2S where they can practice performing their duties and enhance emergency planning and readiness. These drills should be realistic simulations where equipment is deployed, communications gear is tested, and workers role-play as rescuers and victims. After drills, contingency plans should be revised and retested until those responsible for the plan are confident the plan is operational.



Training is a necessary part of protecting workers

Sources of Hydrogen Sulfide

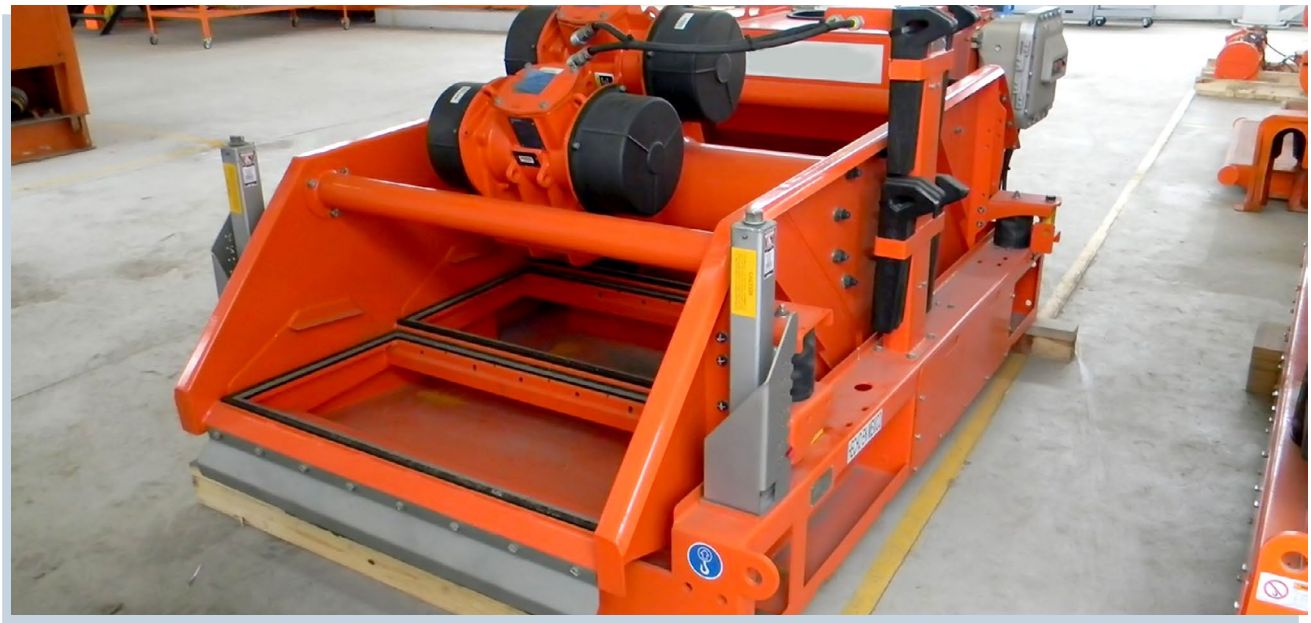
H_2S can occur naturally or be produced during industrial processes. H_2S is produced in nature primarily through the decomposition of organic material by bacteria. Natural H_2S can also develop within low-oxygen environments, such as bogs, swamps, and polluted water. H_2S also forms part of natural gas, petroleum and crude oil, sulfur deposits, volcanic gases, and sulfur springs. When people refer to certain crude oils as "sour," they are referring to H_2S found in that crude oil.

During industrial operations, H_2S can form as a product, byproduct, or waste material. Companies often attempt to recover byproduct H_2S and convert it into elemental sulfur or sulfuric acid, also known as battery acid.

During oil and gas well-drilling operations, H_2S may be released at the shale shaker area, the circulation fluid treatment areas, during tripping procedures, at the wellhead, at the cellar, and onto the drilling floor.

Environments laced with H_2S are known as "sour" environments. Sour environments are defined as

Volcanic gases



A shale shaker

fluids that contain water and H_2S. Water injection and other enhanced recovery operations may introduce bacteria into the pipelines that produce soluble H_2S. The H_2S can accumulate over time and leak into produced fluids. Treat drilling fluids before drilling to prevent H_2S buildup. Your company should have a drilling treatment plan in place before you ever begin work.

Some companies produce H_2S for use in manufacturing. These companies will have containers of H_2S stored in their buildings and eventually transport the gas to other companies. Each H_2S container must have certain label elements to warn workers of its dangerous contents. You may see containers labeled with Globally Harmonized System (GHS) or National Fire Protection Agency (NFPA) ratings.

Physical and Chemical Properties

H_2S may be called rotten egg gas, swamp gas, sour gas, meadow gas, stink damp, devil's breath, and many other names. You may see it listed in chemical manuals as sulfuretted hydrogen, hydrogen sulphide, hydrosulfuric acid, or dihydrogen sulfide. In Spanish, H_2S is called "sulfuro de hidrógeno" or referred to as "gas venenoso." These names all refer to the same toxic gas. H_2S goes by so many unusual names because of its distinctive smell at low concentrations.

The chemical formula for H_2S is two parts hydrogen and one part sulfur. H_2S is an inorganic sulfide that is highly toxic and colorless. Because of its toxicity, the EPA has classified H_2S as hazardous waste, and it must be transported and disposed of as such. Concentrations of H_2S are measured in parts per million (ppm) or percentages.

H_2S is slightly heavier than air with a density of approximately 1.5 grams per liter (g/L) and a vapor density of 1.19 at 32°F at 760 millimeters of mercury (mmHg). This means that H_2S is approximately 19% heavier than air at an equal temperature and tends to collect in low-lying areas because it will sink below the lighter air you breathe. The gas will also collect in confined spaces.

Parts per million	Percentages
1,000,000 ppm	100%
100,000 ppm	10%
10,000 ppm	1%
1,000 ppm	0.1%
100 ppm	0.01%
10 ppm	0.001%
1 ppm	0.0001%

Areas of Potential H_2S Exposure		
- Cellars - Confined spaces - Containments dikes - Heater treaters	- Manholes - Manure pits - Mud systems - Pits	- Sewers - Tanks - Trenches - Vacuum trucks

H_2S will collect in any enclosed facility or piping that contains H_2S gas or H_2S-contaminated fluids, including the examples listed in the Areas of Potential H_2S Exposure chart.

H_2S has a very low melting point (-117.2°F), so it will almost always be a gas. H_2S can also be compressed into a liquid gas and transported by sea, highway, rail, air, or pipeline.

H_2S has a dangerous flammable limit of 4.3%-46% vapor by volume in air, which means it is extremely flammable. The gas can spontaneously combust at high temperatures. H_2S is also quite explosive. It has an auto-ignition temperature of 500°F and an extremely low flashpoint of -76.4°F. When H_2S contacts strong oxidizers, such as bleach or hydrogen

Bleach and hydrogen peroxide are strong oxidizers

peroxide, it can cause fires, explosions, or metal damage.

H_2S is soluble in (can dissolve in) water and oil, but its solubility decreases as the temperature of the liquid rises. When H_2S dissolves in water, it forms an acid that can corrode metal.

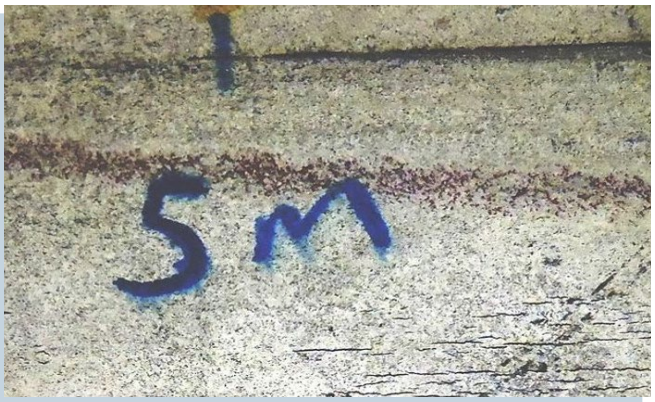
H_2S causes severe corrosion to metals, such as copper, carbon steel, steel, silver, brass, and bronze. Metals housing H_2S gas can suffer sulfide stress cracking or become very brittle. If either of these happen, a metal container, such as a pipeline, may fail entirely, causing the gas to escape into the open air. To avoid metal corrosion, treat drilling fluids (and other products as necessary) to chemically reduce the corrosive properties of H_2S before you start work.

Physical and Chemical Properties of H_2S

Property	Characteristics	Hazards
Toxicity	- Highly toxic	- Causes severe health effects if inhaled
Density	- Density: 1.5g/L - Vapor density: 1.19 at 32°F at 760 mmHg - 19% heavier than air	- Collects in low-lying areas and confined spaces
Flammability	- Flammable limit: 4.3% – 46% vapor by volume in air	- Extremely flammable - May spontaneously ignite at high temperatures
Melting point	- Melting point: -117.2°F (very low) - Can be compressed into a liquid and transported by sea, highway, rail, air, or pipeline	- H_2S is almost always in gas form, meaning it will be invisible to you - If in compressed liquid gas form, can cause frostbite upon contact
Combustibility	- Auto-ignition temperature: 500°F - Flashpoint: -76.4°F (extremely low)	- Quite explosive - Transported containers of compressed H_2S may explode if exposed to fire or handled carelessly
Reactivity	- Reacts with strong oxidizers (e.g., bleach, hydrogen peroxide) to cause fire, explosions, or metal damage - Reacts with many metals (e.g., iron, steel) - Can dissolve in water and oil	- Produces toxic SO_2 gas when burned - Forms metal sulfides that spontaneously ignite when exposed to air - When dissolved in water, forms weak acid that corrodes metal - Severely corrosive to metals, such as steel, carbon steel, copper, silver, brass, and bronze

Many metals (like iron or steel) will react with H_2S to form metal sulfides, which can spontaneously ignite when exposed to air. For example, H_2S will react with iron or spent iron sponge (a treating material) to produce iron sulfide, which can auto-ignite and burn when exposed to air. When exposed to air, iron sulfide should be kept wet until it can be disposed of.

H_2S is highly toxic, which means that exposure to H_2S can affect your health. H_2S gives off an unpleasant odor similar to rotten eggs that is easily detected at low concentrations. At high concentrations, H_2S impairs and even temporarily eliminates your sense of smell. Because of the rapid onset of olfactory fatigue and paralysis (loss of the sense of smell), do not rely on odor as the only warning for the presence of H_2S. At higher concentrations, H_2S also causes severe health effects if inhaled.



Pipe corroded by H_2S

Routes of Exposure

You can be exposed to H_2S through inhalation or skin contact. Practice good personal hygiene to help prevent any damage to your health. The exposure that poses the greatest danger to workers is death by inhalation. Skin absorption of H_2S is minimal, but it is a concern when you are exposed to compressed liquid H_2S. Concentrations of H_2S above 10 ppm are generally regarded as unhealthy for continuous exposure. Ten ppm of H_2S is the industry accepted exposure level. Check with your client and operator for their accepted exposure level.

Limits of Exposure

OSHA, NIOSH, and ACGIH have exposure limits set for H_2S to protect workers from harm. Note that their exposure limits are for air levels only. If liquid H_2S touches your skin, you can become overexposed even if the H_2S concentration in the area is lower than the exposure limit. The Hydrogen Sulfide Workplace Exposure Limits table lists the exposure limits from each organization. If the H_2S concentration is at or above 100 ppm, it is immediately dangerous to life or health (IDLH), and you will need special PPE to work in that environment.

H_2S Workplace Exposure Limits

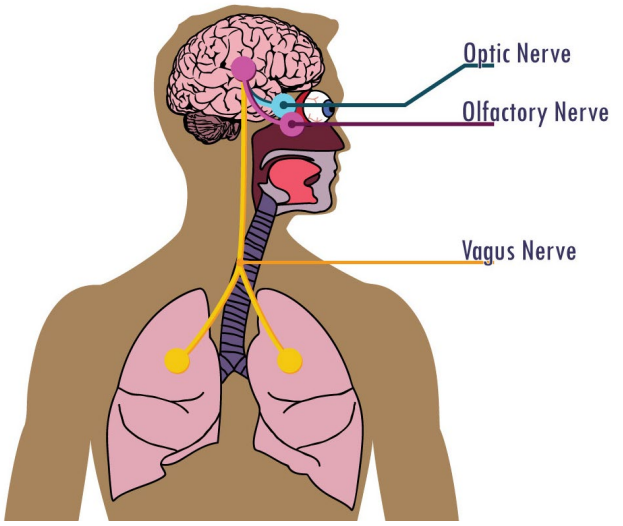
Organization	**Exposure Limit**
OSHA	- ACC: 20 ppm
NIOSH (followed by API and ANSI)	- REL: 10 ppm - IDLH: 100 ppm
ACGIH	- TLV-TWA: 1 ppm - STEL: 5 ppm

Health Effects

When you inhale H_2S, the chemical affects your eyes, nose, brain, lungs, and the nerve pathways that connect them to each other. Specifically, H_2S paralyzes the nerves that interpret smells for your brain. H_2S also impairs the part of your brain that controls your breathing, which can cause you to have trouble with or even stop breathing. Symptom severity depends on the gas concentration and how long you were exposed. Look at the Health Effects of Exposure to Hydrogen Sulfide table, and notice how the health effects become increasingly severe as the H_2S concentration increases.

An H_2S concentration of 1,000 ppm, only 1/10 of 1%, will cause immediate unconsciousness and death.

Reactions to H_2S can vary from person to person because everyone is different. You may be more susceptible or sensitive to the effects of H_2S because of any of several factors. These individual variables include body mass, overall physical condition, age, smoking habits, and personal biochemistry. For example, if you have asthma, you will be more sensitive to lower concentrations of H_2S and may have trouble breathing sooner than workers who do not have asthma. Other variables that affect your reaction to H_2S include the exposure concentration, frequency, and duration.



H_2S affects these nerve pathways

If you smoke cigarettes, drink alcohol, or take prescription medications or illicit drugs, you may be more sensitive to the effects of H_2S. These substances are toxins that your liver normally filters out of your

Health Effects of Exposure to Hydrogen Sulfide	
1 ppm	- Can smell H_2S odor
10 ppm	- Headaches, dizziness, nausea and vomiting, coughing, difficulty breathing
20 ppm	- Irritated, inflamed eyes and irritated airways after 1 hour of exposure
50 ppm	- Sense of smell eliminated after 15 minutes or more of exposure
100 ppm	- Loss of sense of smell after 3 minutes - Respiratory tract and eye irritation
200 ppm	- Sense of smell eliminated almost instantly - Burning eyes and nose
500 ppm	- Unconscious after brief exposure - Victim will not be able to breathe if not treated quickly
700 ppm	- Unconscious almost instantly - Breathing stopped - Victim will die if not rescued right away
1,000 ppm	- Instant unconsciousness - Permanent brain damage or death

body. If you have taken or used any of these before you are exposed to H_2S, your liver has to filter multiple toxins out of your bloodstream. As your liver works harder to clean your blood, it may become overwhelmed and stop metabolizing at its normal rate, allowing toxins to linger and compounding the effects of H_2S on your body.

You can also become more sensitive to the effects of H_2S naturally. If you are repeatedly exposed to low concentrations of H_2S over a long period of time, you can become sensitive to the substance. When you are exposed again, you may experience increasingly severe health effects at lower concentrations. Wearing contact lenses can also make you more sensitive to the effects of H_2S. Wearing contact lenses while working in an H_2S environment could cause eye irritation. Some operators may not allow workers to wear contact lenses on their site.

There are two categories of health effects: acute and chronic. Acute effects occur after exposure to a high concentration of H_2S over a short period of time. Chronic effects occur when you come into contact with low concentrations of H_2S over a long period of time.

Acute Toxicity

Acute exposure can lead to acute toxicity, the health effects that are the result of a single dose or exposure to a substance. A single breath of H_2S at about 1,000 ppm can paralyze your respiratory system and result in convulsions, coma, and death. To see what symptoms can result from acute toxicity caused by H_2S, read the Symptoms of Hydrogen Sulfide Exposure table.

Chronic Toxicity

Chronic exposure is when you come into contact with low concentrations of H_2S over a long period of time. Chronic exposure to H_2S has been known to cause low blood pressure, loss of appetite, weight loss, and chronic cough. Neurological symptoms, including psychological disorders, have also been associated with chronic exposure. To see what other symptoms can result from chronic toxicity caused by H_2S, read the Symptoms of Hydrogen Sulfide Exposure table.

Symptoms of Hydrogen Sulfide Exposure

Sensitivity	Chronic Toxicity	Acute Toxicity
- Loss of sense of smell - Excitement or giddiness - Eye irritation - Coughing and sneezing - Headaches - Nausea - Diarrhea - Dizziness and confusion - Staggering gait - Sensitivity to light [seen as "photophobia" on Safety Data Sheet (SDS)] - Respiratory tract irritation - Fluid in the lungs (seen as "pulmonary edema" on SDS) - Respiratory arrest - Cardiac arrest - Brain damage - **Death**	- Eye irritation - Headaches - Nausea - Loss of appetite (seen as "anorexia" on SDS) - Sleep disturbances - Respiratory tract irritation - Corneal blistering, pitting, and opacity - Fluid in the lungs	- Inflamed eyes - Headaches - Fatigue - Irritability - Trouble sleeping - Trouble eating or digesting food - Weight loss

Communicating the Hazards of Hydrogen Sulfide

Warning Signs and Alarms

Companies use OSHA-required warning signs to mark areas contaminated with H_2S. These warning signs correspond to the concentration of H_2S within the area.

All well-drilling sites will be classified based on whether H_2S is present or not. There are three types of warning signs posted around H_2S areas. These three signs have color-coded flags based on the severity of the hazard. These flags correspond to classified API conditions. There are four API classifications for H_2S areas: No Hazard Condition, API Condition I – Low Hazard, API Condition II – Medium Hazard, and API Condition III – High Hazard. These classifications are based on potential or actual exposure to H_2S. For information about each hazardous API Condition, read the API Hydrogen Sulfide Conditions table.

API Condition II flag shown with H_2S warning sign

API Hydrogen Sulfide Conditions

API Condition	Suspected H_2S Concentration (ppm)	Requirements	Minimum Necessary Special Safety Equipment	Assigned Flag
No Hazard Condition	Negligible or no amount of H_2S	- No special equipment required	- None	- None
API Condition I – Low Hazard	Less than 10 ppm	- Safety equipment readily accessible	- Oxygen resuscitator - H_2S detector	- Green
API Condition II – Medium Hazard	10 ppm – 30 ppm	- Audible and visual alarms in place - Safety equipment readily accessible	- Oxygen resuscitator - H_2S detector	- Yellow
API Condition III – High Hazard	Greater than 30 ppm	- Warning signs posted within 500 ft. of area at all entrances in addition to signs at entrances to space - Safety equipment readily accessible - Inspect all H_2S safety equipment before entering - Emergency procedures and emergency contacts in place - At least 2 exits available - No untrained workers allowed in area	- 1 metered H_2S detector - 1 pump H_2S detector - Respiratory protection - Oxygen resuscitator - 3 wind socks or streamers - 2 NIOSH-approved 30-minute escape pack SCBAs	- Red

Alarms you can hear and see must be set up around H_2S areas to coordinate with H_2S monitors. Alarms should sound when an H_2S monitor picks up a certain H_2S concentration. Different alarms should be set based on how much H_2S is present. The Typical Alarm Settings table shows you which alarms go off at certain concentrations of H_2S under typical alarm settings. When you see flashing lights or hear an alarm, leave the area immediately unless you are trained and authorized to deal with an H_2S emergency.

Engineering Controls

Companies use engineering controls as the first way to protect you from H_2S. Companies work from a long list of controls to keep you from being exposed to high concentrations of H_2S. Training must include discussion about site-specific engineering controls. Workers must be familiar with the following:

- Design or remodeling of worksites
- Enclosed worksites
- Ventilation and monitoring equipment
- Metallurgical properties of equipment
- Burning, flaring, and venting of H_2S
- Containment and dispersion

Most companies prefer to use local exhaust or natural ventilation to control the amount of H_2S in the air. Enclosing the H_2S producing process can also keep H_2S out of the air. All of these controls must be in place to keep exposure as low as is reasonably achievable.

Burning and Flaring

Some companies provide flaring or venting lines when H_2S could be present in concentrations over 15 ppm. These lines provide an engineering control designed to reduce worker exposure. Companies may burn off the H_2S gas to prevent it from accumulating in the work area. Burning and flaring H_2S produces SO_2. To protect yourself during burning and flaring operations:

- Monitor the SO_2 concentration in the air with portable or strategically placed fixed devices capable of detecting a minimum of 2 ppm SO_2
- Take readings at least hourly and any time workers detect SO_2 odor or nasal irritation
- Use the protective measures specified in your company's H_2S contingency plan if the SO_2 concentration in the work area reaches 2 ppm
- Select and wear the appropriate PPE following the guidelines listed in your company's H_2S contingency plan
- Calibrate SO_2 monitors every 3 months, or as recommended by the manufacturer

Burning and flaring

Sulfur Dioxide

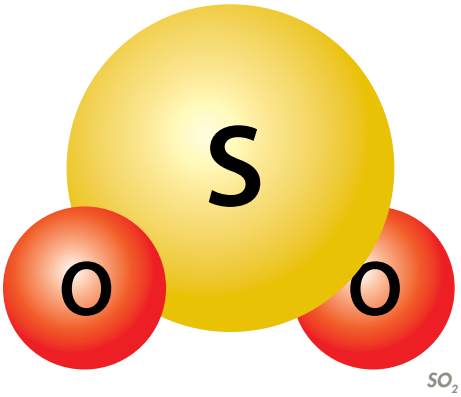
When H_2S burns, it forms another toxic gas, SO_2. Iron sulfide, a product of an H_2S reaction with iron, will also produce SO_2 when burned. SO_2 is a very irritating toxic gas that is colorless and has a burned match odor. Its vapor density of 2.26 at 32°F under normal atmospheric pressure (760 mmHg) means that SO_2 is also heavier than air and will collect in low-lying areas and confined spaces. When someone inhales SO_2, it produces sulfurous acid on the nose and throat membranes and they suffocate.

SO_2 exposure mainly affects your eyes, throat, and lungs. As you are exposed to higher concentrations of SO_2, symptoms become increasingly severe. Chronic exposure to SO_2, or exposure to low concentrations over a long period of time, can alter a victim's sense of smell and taste, cause exercise-induced shortness of breath, predispose you to frequent respiratory infections, and increase your risk of developing chronic cold symptoms, known as nasopharyngitis.

To protect yourself from SO_2 exposure, API recommends you wear either a positive-pressure, full-facepiece supplied air respirator (SAR) and an escape pack, or an SCBA in any area with SO_2 concentrations at or over 2 ppm over an 8-hour time-weighted average (TWA). OSHA sets its permissible exposure limit (PEL) for SO_2 at 5 ppm over an 8-hour TWA. ACGIH recommends 0.25 ppm as a short-term exposure limit (STEL) averaged over 15 minutes. The Sulfur Dioxide table shows how symptoms become increasingly severe as you are exposed to higher concentrations of SO_2.

Administrative Controls

Administrative controls, or proper work procedures and practices, are the second way companies protect you from H_2S. Administrative controls can greatly reduce the number of H_2S-related accidents. Your company should verify that you are trained to handle H_2S environments and conduct site-specific safety meetings (tailgate meetings).



SO_2 molecule


Observing a windsock will tell you what direction to evacuate in

Typical Alarm Settings

	Alarm Level	H_2S Concentration	Warning Signal
On Land	Low alarm	10 ppm	Flashing amber light
	High alarm	20 ppm	Intermittent siren
Offshore	Low alarm	10 ppm	Flashing amber light
	High alarm	20 ppm	Intermittent siren and flashing red light
	Very high alarm	50 ppm	Continuous siren and flashing amber and red light

Sulfur Dioxide	
Concentration in air in ppm	**Exposure Limits and Typical Characteristics**
0.25 ppm	- ACGIH STEL
1 ppm	- Burned match odor - May cause respiratory changes
2 ppm	- NIOSH REL - API action level
5 ppm	- Burning eyes, breathing irritation, and minor throat irritation - OSHA PEL - NIOSH STEL
12 ppm	- Throat-irritating cough - Constriction in chest - Watering eyes - Nausea
100 ppm	- IDLH
150 ppm	- Extreme irritation - Can be tolerated for only a few minutes
500 ppm	- Causes a sense of suffocation, even with the first breath - Rescue promptly and apply artificial ventilation and CPR techniques
1,000 ppm	- Death may result unless rescued right away - Immediately start artificial breathing and CPR

Your company must provide you with site-specific, hands-on H_2S training before you may work in an environment contaminated with H_2S. After you have completed all required H_2S training, remember to obtain all required work permits before you start work in H_2S environments.

During work, use the safe work practices we will discuss in this section. If you feel that your work is putting you in danger of death or serious physical harm or could cause significant environmental harm, it is your right (and the right of all workers) to use Stop Work Authority (SWA) to stop work. Use SWA as necessary. Attend and participate in company provided safety meetings. These meetings should be held before each job involving H_2S. Make sure you perform a job safety analysis (JSA) before you start work. Now we will discuss other administrative controls, including observing wind conditions, controlling ignition sources, performing ventilation and air monitoring, and using the buddy system.

Make sure that all required permits are used and that compliance is maintained with the requirements of the permit.

Wind conditions tell you which way H_2S will spread. Stay aware of wind conditions and direction at all times. Check the wind sock or streamer regularly and any time you are unsure which direction the wind is blowing. Whenever possible, start on the upwind side when working on equipment. Make sure you are not downwind of an H_2S source. Have an escape route, and know where the exits are in case you have to get out immediately. Always move crosswind and then upwind to get away from a source of H_2S. If you notice the smell of H_2S or hear an alert or alarm, stop breathing and don your escape pack respirator, if applicable.

Always ventilate before beginning work

Leave the area immediately going crosswind (at a right angle) and then upwind.

Use non-sparking tools, non-sparking corrosion-resistant ventilation systems, approved explosion-Perform a thorough check for workers and ignition sources in the area before you start any potentially hazardous work. Notify your supervisor before you start operations that could release H_2S. If you are working in a permit-required confined space, maintain compliance with the permit requirements. Ventilate work areas, vents, and purge lines on vessels before beginning work. Always maintain continuous air monitoring while working in confined spaces. Never take shortcuts, and always follow all procedures.

Use the buddy system when working in H_2S areas. When using the buddy system, workers are paired off so that if one buddy is struggling, the other buddy can assist or call for help. When you are paired off, look out for your buddy. Make sure you maintain contact with your buddy, and know where they are at all times while in the H_2S area. Keep all non-essential workers away from the area to reduce unnecessary H_2S exposure. As a buddy, you must be able to:

- Help your buddy with rescue operations if trained
- Observe your buddy for signs of hazardous exposure
- Periodically check your buddy's PPE to make sure it is still sound
- Notify the appropriate person if your buddy needs emergency help

The buddy system is also a useful tool in other hazardous situations. Having a buddy while you enter confined spaces and hazardous areas is a good practice. Make sure all workers working in any of these situations are properly trained. Your company may also have a lone worker policy. If so, review the policy and ask your supervisor if you have any questions.

Verify that proper safety equipment is available and functioning. Make sure safety equipment is used when necessary. Every worker must know where safety equipment is stored and how to use it. Make sure you are monitoring H_2S conditions using an H_2S monitoring system.

Worker is Severely Injured in Hydrogen Sulfide Explosion

A contractor was checking the oil level on a tank. He was using a metal wrench to remove an access panel, when hydrogen sulfide inside the tank exploded, throwing him into his truck, which was parked 40 yds. away. He suffered multiple broken bones, internal injuries, and burns over 85% of his body.

What went wrong?

1. He was using a metal tool, which can cause sparks during work. Hydrogen sulfide is highly explosive, so workers should use non-sparking tools around areas that may be contaminated with hydrogen sulfide. [29 CFR 1910.106(e)(6)(i)]

Did you find anything else that may have contributed to this accident?

2. There was potentially a lack of training on safe work practices.

3. The worker should have continuously grounded himself by maintaining contact with the ladder or handrail to prevent static buildup.

4. Monitoring was not conducted, therefore the work environment should have been considered IDLH.

5. The worker was not wearing appropriate PPE, i.e. FRC and a respirator. He would have needed the PPE because the concentrations of hydrogen sulfide were found to be high enough to support combustion and would have far exceeded the PEL and there was no mention of respirator use.

To protect yourself and the equipment you are working on, API recommends the following practices for:

- Hydrogen sulfide service operations
- Drilling and servicing operations
- Production facilities/fluid transfer and maintenance
- Offshore operations
- Gas processing plants

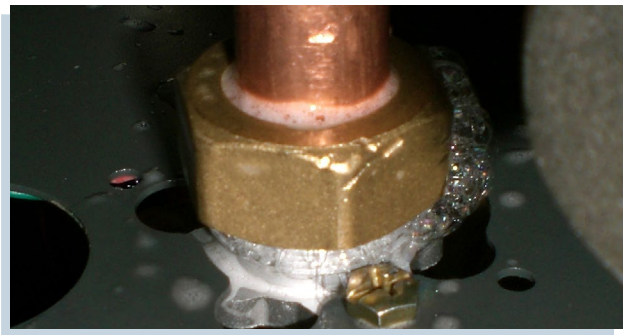
Hydrogen Sulfide Service Operations

Observe flow line and gathering line right-of-ways for abnormal conditions conducive to pipeline failures, such as those caused by excavation, construction, trespassing, dramatic changes in landscape, or surface erosion. Be cautious because you could be exposed to H_2S during excavation.

Inspect valves, flanges, gauges, connections, and liquid storage tanks to see if they need repairs or maintenance. Follow the maintenance schedule for performing tank gauging, water line blowdown, line repair, valve replacement, and sampling so that H_2S release hazards can be avoided.

Test the gas phase of produced fluids periodically to determine the H_2S concentration. Assess significant changes in wellhead pressure, gas-oil-water ratios, flow rates, and similar parameters to prevent leaks or failures. Test annuli of flowing wells at regular intervals for any pressure changes because pressure changes can indicate a down-hole failure of the packer, tubing, or casing. Test relief valves and other applicable components on pressure vessels according to regulatory requirements or company policy.

Review your company's corrosion monitoring program to detect and mitigate internal and external corrosion activity. Observe artificial lift wells for any change in operating conditions that could cause leaks or failures. Use visual observation, soap bubble testing, portable detection equipment, and fixed monitoring equipment to detect H_2S leaks, especially in enclosed facilities.



A soap bubble test can detect small leaks

Drilling and Servicing Operations

Test tanks for H_2S. If the H_2S concentration exceeds or could exceed 10 ppm during sampling or tank gauging operations, more controls are needed and workers must wear respiratory protection during these operations.

When abandoning facilities, pipelines and flow lines left in place should be purged and bullplugged, or otherwise capped. Take precautions to prevent an iron sulfide fire. Check vessels for the presence of naturally occurring radioactive material (NORM). Vessels must be flushed with water, purged, drained, locked out and tagged out by blinding or isolating equipment, and left open to the atmosphere.

811®

Know what's below.
Call before you dig.

Take necessary precautions during the following operations because H_2S may be present:

- Plugging and abandoning wells
- Hydraulic fracturing (also known as fracking)
- Snubbing
- Perforating (also known as perfing)
- Acidizing
- Fishing
- Tubing
- Wireline
- Any other drilling or workover operations

When performing a hydrochloric acid treatment on a produced water injection well, the hydrochloric acid can react with iron sulfide scale in the well bore/rig tank to create H_2S gas. Workers or the supervisor should anticipate the potential H_2S hazard. Adequate mitigation steps should be in place to protect workers from potential H_2S exposure. Inform all contractors and well-site supervisors about the requirement to monitor LEL/H_2S when flowing back to an open tank. Make sure workers onsite are equipped with personal monitoring devices when required. Use a JSA before this type of work to review the specific issues that relate to the concentrations and procedures for that site. Make sure company and contractor workers know that acidizing procedures include the potential hazard of H_2S as a byproduct. Remind everyone that they have SWA.

A Worker Collapses During Acidizing

A worker was exposed to H_2S gas while performing a hydrochloric acid treatment on a produced water injection well. The worker was positioned on top of the rig tank, adding neutralizing agent to the fluids returning from the acidized well. He was exposed to vapors from the tank, felt dizzy, and began descending the stairs from the rig tank. It is believed that he lost consciousness while descending the stairs, falling to the ground at the base of the tank. He immediately regained consciousness and with assistance was transported to the local medical center. He was checked out and returned to work the next day. Readings taken at the rig tank shortly after the incident indicated concentrations of 30 ppm H_2S and during a re-enactment, readings of up to 80 ppm H_2S were generated while the neutralizing agent was being added. This field has consistently measured concentrations of less than 1 ppm H_2S.

What went wrong?

1. The hydrochloric acid reacted with iron sulfide scale in the well bore/rig tank, creating H_2S gas. The potential hazard of H_2S was not anticipated by the workers or the job planner. Therefore, adequate mitigation steps were not in place to protect the workers from H_2S exposure. Isolated, similar concentrations of H_2S had been noted in past acid jobs but were not effectively communicated.

Did you find anything else that may have contributed to this accident?

1. _____

Discuss the recommended preventative actions submitted by the shown in the PowerPoint with your instructor.

1. Make sure well files and program templates indicate that pumping hydrochloric acid may create or release H_2S.
2. Issue a Safety Alert on to increase H_2S awareness.
3. Inform all contractors and well site supervisors of the requirement to monitor for LEL/H_2S when flowing back to an open tank.
4. Make sure workers on site are equipped with personal monitoring devices when required.
5. Use a JSA before this type of work to review the specific issues relating to the concentrations and procedures for that site.

6. Modify the practice of flowing back live acid into an open tank.

7. Modify the practice of adding neutralizer so workers are not exposed to vapors or gases from the tank.

8. Make sure company and contractors acidizing procedures include the potential hazard of H_2S as a byproduct.

9. H_2S may be released during a kick or burp during drilling or work over operations. A kick or burp is an entry of water, gas, oil, or other formation fluid into the wellbore during drilling or work over. It occurs because the pressure exerted by the column of fluid in the wellbore is not great enough to overcome the pressure exerted by the fluids in the formation drilled.

Production Facilities/Fluid Transfer and Maintenance

Production tanks and facilities can contain substantial volumes of hydrocarbons and H_2S. When performing tank gauging, thieving (sampling), fluid transfer, or maintenance operations, special precautions should be taken to protect yourself from these hazards. Also be aware that haulers transporting production water are not required by Federal DOT to label or placard their loads, even though these tanks may contain an H_2S hazard. Products going into these tanks with concentrations as low as 0.2 ppm could potentially create H_2S atmospheres that are above occupational exposure levels (OELs) that require respiratory protection. Concentrations of 2 ppm could potentially create H_2S atmospheres that would reach IDLH levels in the tank headspace with a 50:1 ratio. Workers should follow operator or company operating procedures when they encounter these conditions. Operating procedures could include:

- Following JSA and SWA procedures
- Noting wind direction from a windsock or streamer
- Using extreme caution on foggy days and days with little or no wind, especially after sundown
- Using non-spark-producing tools and equipment
- Grounding to bare metal before opening hatches, valves, flanges, hoses, or pots

A pot is the catch pan that encircles the cam lock hose connection that hooks up to storage tanks for drivers to transfer product from the tanks to the trucks to transport the product. There are also scrubber pots, or scrubbers, that are placed where product is collected and either separated or treated.

- Paying close attention when opening fiberglass or tanks that are not grounded
- Standing upwind from the thief hatch or source of the H_2S
- Opening tanks downwind first and working towards the upwind tanks last
- Keeping your head away from the tank opening
- Waiting for the pressure to dissipate before gauging, connecting hoses, or removing valves and flanges

Non-pressure liquid storage tanks

TANK HAZARD ALERT

gauging • thieving • fluid handling
how to recognize and avoid hazards

designed by: PEC SAFETY

Opening thief hatches of storage tanks can lead to the rapid release of high concentrations of hydrocarbon gases and vapors. Those may result in very low oxygen levels and toxic and flammable conditions around and over the hatch. Recent reports have documented fires or explosions, and described workers experiencing dizziness, fainting, headache, nausea, and, in some cases, death while gauging tanks, collecting samples, or transferring fluids. **Tank gauging, thieving, and fluid handling can be performed safely with proper precautions.**

hazards that workers can encounter

- oxygen deficiency
- fires & explosions
- chemical toxicity
  - hydrocarbon vapors
  - propane
  - butane
  - benzene
- hydrogen sulfide (H_2S)

potential effects of exposure

- death
- chronic illness
- flash fire burns
- dizziness
- irregular heartbeat
- irregular breathing
- respiratory irritation
- fatigue
- nausea
- eye irritation
- headache

EMPLOYERS:

Must Conduct Exposure and Hazard Assessments at Worksites to determine needs for:

- Engineering Controls
- Respiratory Protection
- PPE
- Monitoring Device such as:
  - ▸ Multi-gas meter
  - ▸ Other direct-reading toxic gas meter (benzene)

Must Provide Training to Workers:

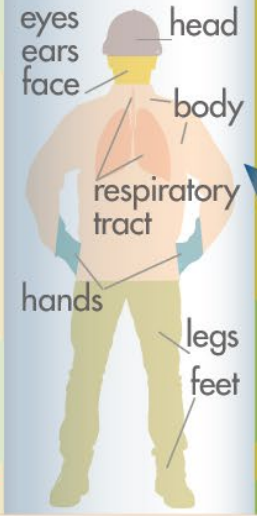
- Hazard Communication
- Lone Worker Policy
- Proper use of PPE and respiratory protection
- Types, use, and limits of respiratory protection equipment as appropriate
- Recognizing ignition sources
- Tank Gauging work practices/procedures
- Emergency Response Plan
  - ▸ Procedures for alarm response and site re-entry
- Use and limits of toxic- or multi-gas meter for O_2, H_2S, LEL, and CO

Should Implement Engineering Controls such as:

- Remote Gauging
- Closed Loop Systems
- Auto Gauging
- Sight Glasses/Gauges
- Remote Venting

Verify sub-contractors are following work practices/procedures

PPE protect your



WORKERS:

Your employer has established safety procedures for your protection including a **Hazard Assessment** and Work **Practices/Procedures**

Follow your employer's **Hazard Assessment** and Established Work Practices/Procedures

- **Use** toxic- or multi-gas **meter** provided by your employer as per your training
- **Heed** all **alarms**
- **Stop flow** into tanks prior to gauging, **when possible**
- **Minimize leaning** over open hatches – **stand away**/upwind/crosswind when possible
  - ▸ **Inversion**/high humidity/**lack of wind** could **increase danger**
- **Follow** your employer's **"lone worker" policy**
- **Allow tanks to ventilate** after opening thief hatches
- **Evacuate** unsafe work areas and **report immediately**
- **Know the limits** of your **respiratory protection** as provided during employer training
- Immediately **report** any **health symptoms**

Wear PPE as required/provided

Attend **Hazard Communication** Training

Be Aware of Potential **Ignition Sources:**

- Static
- Cell phones
- Sparks from tools or metal objects
- Open flames
- Non-approved electrical equipment/devices
- Ensure proper grounding/bonding

If you are not sure, **STOP** the job and ask!

Everyone has the right to STOP work that is unsafe.

YOUR LIFE can change in a **SINGLE BREATH** or with **ONE SPARK.**

A Worker Dies While Tank Gauging

A worker was gauging a tank when she realized the tank was full, so she started to divert the supply line to another tank. The shutoff valve blew out, releasing sour crude and hydrogen sulfide. She tried to walk away but only made it about 15 ft. before she was overcome by the gas and died. When investigators inspected the incident, they found a personal gas monitor, a 30-minute SCBA, and a SAR sitting inside her vehicle, unused.

What went wrong?

1. No air monitoring was performed. We know this because the worker left the gas detector in her vehicle. Air monitoring must be performed before tank gauging. [29 CFR 1910.134(g)(2)(i), API RP 55 Section 9.21]

2. She was working alone around potentially high concentrations of hydrogen sulfide. Standby personnel should have been present for air monitoring, and had the hydrogen sulfide concentration been determined, standby workers should have been available for the entire operation. [29 CFR 1910.134(g)(3)(i)-(vi)]

3. She was not wearing respiratory protection and did not have her escape pack with her. Respiratory protection must be worn when the area may contain hydrogen sulfide above the PEL, as is commonly found when gauging tanks containing sour crude. [29 CFR 1910.134(a)(2)]

Did you find anything else that may have contributed to this accident?

4. There was a potential lack of training on safe work practices.

5. There was a potential lack of training on the proper procedure to divert crude to a different tank.

6. There was a lack of training on the characteristics of hydrogen sulfide gas. Supply lines are located at the bottom of tanks. With the first tank in a full condition, the gas would be pressured out of the tank through the vent lines. Once leaving the vent lines, the gas (19% heavier than air) would have settled on the ground near the tanks. This area inside the tank dike is typically where the valve to divert the flow would be located. The tank battery dikes would help the gas build up in this area, possibly contributing to the fatal atmosphere that the worker encountered.

Offshore Operations

Minor problems in onshore environments can be more critical in offshore environments. Offshore operations are typically remote, have compact facilities, and have limited escape and evacuation routes. According to API and BSEE, offshore workers must be regularly trained in the use of oxygen resuscitation equipment. If a hazardous H_2S condition is known or suspected, boats and helicopters should approach the site from an upwind direction when possible.

Gas Processing Plants

Gas processing operations typically include higher volumes of gas containing H_2S, potentially higher concentrations of H_2S, and a greater number of workers and more equipment. Many gas treating and sulfur recovery processes happen in gas processing plants. Because most of these methods result in a concentrated H_2S stream or reaction product, companies using these methods must set up a process safety management program according to 29 CFR 1910.119. Your company should set up a corrosion monitoring program to reduce internal and external corrosion activity that can affect equipment in H_2S service.

If workers are working around gas and liquid handling systems that could contain H_2S concentrations at or higher than 10 ppm, workers should use special techniques to quickly spot and plug any leaks in those systems. These monitoring techniques include visual observation, soap bubble tests, portable detectors, and fixed monitoring equipment. API recommends regularly scheduled inspection of equipment, such as pump seals, for leaks. Your company must keep the results of leak tests for at least 1 year.

A natural gas processing plant

Detection and Monitoring Methods

Your perception of H_2S odors can give a false sense of security to an already unseen hazard. H_2S will quickly paralyze your sense of smell at higher concentrations. Do not depend on your sense of smell to detect the presence of H_2S. Below are the readings, in ppm, at which you would detect the odors of H_2S. If you ever notice the smell of H_2S, hold your breath and leave the area immediately.

Companies must test your work area regularly for H_2S based on a company-created schedule to keep you from being overexposed to it. Air monitoring must be performed before each job and continuously while workers are in the area. Your company may use several different types of monitors for air monitoring, including fixed monitoring, portable monitors, and personal monitors. Only workers who have been specifically trained in how to use H_2S monitors can use them.

Hydrogen Sulfide Concentrations with Noticeable Odors	
H_2S Concentration	**Odor**
0.13 ppm	Minimal perceptible odor
0.77 ppm	Faint but perceptible odor
4.6 ppm	Easily detectable, moderate odor
27 ppm	Strong, unpleasant odor
28 – 100 ppm	Rotten egg odor or sweet, acetone-like odor

Training

When training workers on methods of detection and monitoring, the instructor must emphasize site-specific types of detection and monitoring devices and sampling strategies available. Training must include an explanation of warning alarms and emergency response procedures associated with the specific types of detection and monitoring devices.

Training will go over:

- Types of detectors and/or monitors available
- Manufacturer's recommendations
- Purposes, suitability, capabilities, limitations, calibration, function testing, placement, use, and maintenance of detectors and/or monitors available
- Chemicals or other factors that can give inaccurate results (based on the detection method)
- Required hands-on training with the specific H_2S detector to be used in the field

H_2S monitors give readings in ppm. This makes it easy to compare the readings to exposure limits, which are also in ppm. You should receive a user manual for each monitor. The manual should include operating instructions, including how to use the monitor, start up and warm up the monitor, perform zero checks, calibrate, set and test the alarm, perform preventative maintenance, check performance, monitor recovery time after H_2S exposure, and perform troubleshooting.

Keep in mind that monitors cannot be exposed to liquid spray or washdown, so clean them carefully, and keep them out of liquid while conducting air monitoring. The monitor will include a trouble signal that tells you if the machine is malfunctioning. Check your manual for this information, and make sure you know the trouble signal for emergencies.

Fixed Monitor Service and Calibration

All H_2S monitors must be serviced and tested according to the manufacturer's recommendations. Monitors must be calibrated at least once every 3 months. The monitors may need to be tested more often depending on which sector of the oil and gas industry you work in.

During offshore operations, calibrate fixed monitors according to the following requirements per MMS 30 CFR 250.490. When conducting drilling, drill stem testing, well-completion, or well-workover operations in areas classified as H_2S present or H_2S unknown, detectors must be tested at least once every 24 hours. When drilling, begin functional testing before the bit is 1,500 ft. (vertically) above the potential H_2S zone. When conducting production operations, test all detectors at least every 14 days.

Your company must maintain records of testing and calibrations, including dates of testing, in the drilling or production operations report at the facility to show the present status and history of each device. These records must be available for inspection by BSEE personnel for offshore facilities. Note that both portable and fixed H_2S monitors must meet Instrument Society of America (ISA)-S 12.15 requirements.

Fixed Monitors

Fixed monitors continuously monitor H_2S concentrations in a specific location. On offshore sites, monitors must be set up within 10 ft. of equipment that may release H_2S. Fixed monitors are usually located in key areas, such as where workers are likely to be present or where H_2S may be released or accumulate. Fixed monitoring systems must have working alarms that you can both see and hear that correspond to set concentrations of H_2S.

Fixed H_2S monitor

Personal Monitors

Workers must wear personal monitors to stay aware of H_2S concentrations in the air around them as they work. Any time you enter an area where the concentration of H_2S may exceed 10 ppm, you need to wear a personal monitor. If the alarm on the monitor goes off, leave immediately and do not re-enter without the proper respiratory protection.

Personal air monitors should take in samples that represent the air a worker is breathing. You must position the personal monitor's air intake point in your breathing zone to assess the air you are inhaling. This zone encompasses the area just in front of your face and shoulders, a hemisphere with a 6-9 in. radius that centers on your nose. Check with your client operator for their requirements.

To be effective, personal monitors must be attached to workers near the neck and face as close to the mouth and nose as possible to measure the air from the breathing zone.

Personal H_2S monitor

Two Workers Die from Hydrogen Sulfide Exposure

Two workers were getting ready to enter a confined space for maintenance work. They entered the confined space, and after a few minutes, their personal monitors started to go off. There was hydrogen sulfide in the air. Both workers ignored the alarm and continued to work. They were overcome by hydrogen sulfide and died.

What went wrong?

1. The workers ignored the alarms for hydrogen sulfide, which caused their deaths. Workers must wear personal monitors and follow the alarm in areas contaminated with hydrogen sulfide. [1910.146(d)(5)(i), API RP Section 6.3]

Did you find anything else that may have contributed to this accident?

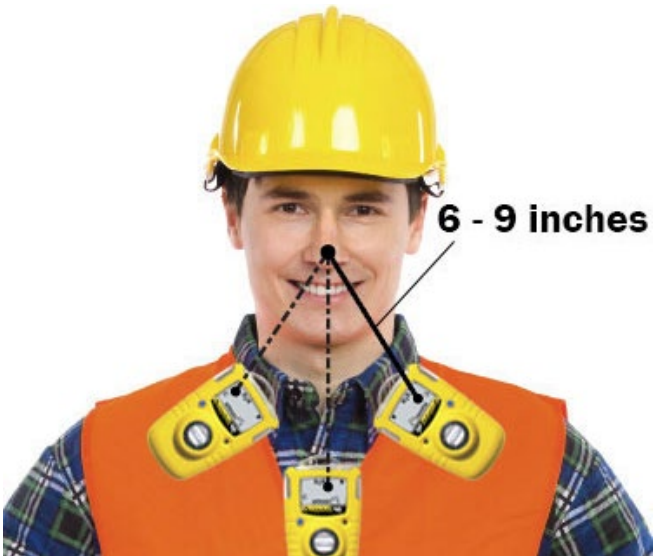
2. There was a potential lack of training on safe work practices.

3. There was a potential lockout/tagout (LOTO) issue.

4. There was a lack of training for the attendant. 1910.134 requires that the attendant must cancel the permit and evacuate the space when conditions exist that are outside the acceptable entry conditions identified on the permit. The attendant is also required to be trained to maintain communication with entrants. The attendant should also be trained to recognize that symptoms of hydrogen sulfide or oxygen deficiency, which could have caused the exposed workers to have poor judgement and decision making. The attendant should have notified rescue personnel and evacuated the space.

Portable Monitors

Portable monitors, also known as gas detectors, are designed to be placed between workers and the source of H_2S or in a confined space. Workers that are required to use portable gas detectors must be trained on their use, maintenance, and calibration. Workers must receive hands-on training with the specific H_2S detector they will be using in the field. Your company must document and keep a record of all training you receive. Now that we know what gas detectors are, let us learn how to use them in the field. Alternatively, some companies may have you use colorimetric gas detector tubes to monitor H_2S. Colorimetric gas detector tubes are made from



The breathing zone

high-quality borosilicate glass tubes with a uniform inside diameter. Inside, each tube is packed with a gas detecting reagent. When both ends of a detector tube are broken, inserted into the pump, and an air sample is pulled through the tube by means of pulling back on the pump handle, the detecting reagent changes color. The length of the discolored layer is proportional to the concentration of the gas or vapor in the sample because of the fixed volume of sample, which is always 100 milliliters. Graduations printed on the tube showing the gas concentration make it fast and easy to take a reading with detector tubes. However, note that the accuracy of a colorimetric gas detector tube reading is +/- 5 to 25%.

Using a Gas Detector

As a worker, it is your responsibility to monitor all potentially hazardous atmospheres before entering to determine if there are hazardous gases present. Monitoring is especially important before working in confined spaces or performing hot work. The gas detector used to identify atmospheric hazards must be a properly calibrated, direct-reading instrument. Gas testing must be conducted by someone knowledgeable in the use of the instrument and familiar with the confined space. Most companies will purchase a multi-gas detector that checks the space for oxygen, LEL (combustible gas), carbon monoxide, and H_2S. If a multi-gas detector is not being used, the atmosphere must be tested in the following order:

1. Oxygen
2. Flammable and combustible gases
3. Suspected toxic gases (carbon monoxide and H_2S)

Monitoring for Potentially Hazardous Atmospheres

Atmospheric Condition	Acceptable Entry
Oxygen	19.5% to 23.5%
LEL (combustible gas)	0% to 10% (many companies only allow 0%)
Carbon monoxide	0 ppm to 25 ppm
H_2S	0 ppm to 10 ppm

This order is important because many combustible gas detectors work by burning the gas inside the detector. If oxygen levels are inaccurate, this could cause false readings. Compare you readings to the acceptable entry conditions shown in the Monitoring for Potentially Hazardous Atmospheres chart.

If hazardous atmospheric conditions are found, do not allow anyone into the area until it has been deemed safe for entry. Ventilate the space to reduce the atmospheric contaminants to a safe level. After starting ventilation, wait a minimum of 10 minutes and then test the atmosphere again to determine if the ventilation is improving the atmosphere. If you suspect that there may be other gases present, your company must periodically monitor the atmosphere to determine their presence.

Gas detector

Gas Detector Operation

All gas detectors will have different characteristics. Be sure that you are familiar with the make and model of the gas detector you will use. It is important to read the user manual before you begin using a gas detector.

When turning on a gas detector, make sure you are in an atmosphere similar to the one you will be working in (i.e. humidity, temperature, dampness, etc.) to avoid false readings. Making sure the atmosphere is clean and free of atmospheric hazards is important because the gas detector will auto-span (automatically calibrate for oxygen).

When testing the atmosphere in confined spaces, the monitor will need to be equipped with pump and suction tubing. This allows you to take direct readings without putting the gas detector itself inside the space. Take readings from various levels, such as in the bottom, the middle, and the top of the space, because certain gases can rest at different levels within the space. For instance, H_2S is heavier than air, so it will settle in the bottom of the space, while methane is lighter than air, so it will rise to the top. Gases will stratify according to their vapor density. How gases stratify will change with environmental conditions, such as temperature and pressure.

When using a gas detector with pump and suction tubing, allow enough time for the air to migrate, or move, to the detector. Wait at least 1 second per foot of tubing (or as per manufacturer recommendations). Gas detectors equipped with a pump may require a bump test. The detector will normally prompt you to block the pump inlet during the startup process to make sure the pump is working properly.

Gas detector equipped with pump and suction tubing

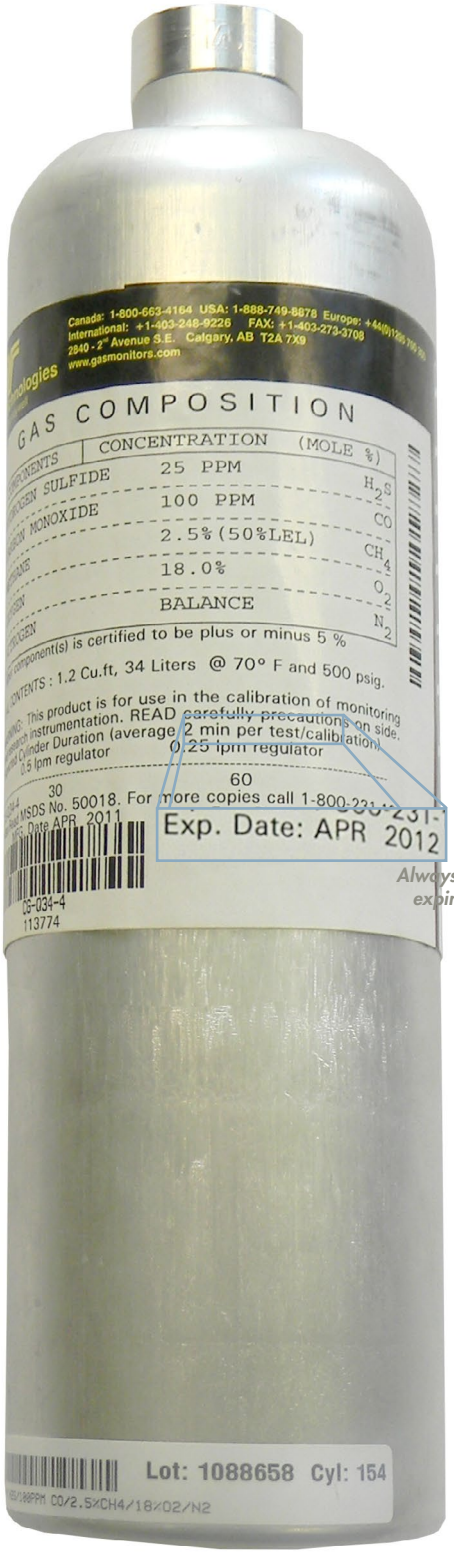
During startup, the gas detector will go through an initial self-test. If the self-test or bump test is not successful, the detector will not work properly. Even if these tests are successful, you still have to conduct a bump test to verify that each sensor is working correctly.

Bump Testing

Bump testing is a way to make sure a gas detector's alarms and sensors are functioning properly. This process exposes the gas detector to a defined concentration of gases. The gas detector needs to be exposed to gases at a concentration that exceeds the lowest alarm setting for each sensor. Exceeding the lowest alarm setting concentration will activate the alarm. If the alarm goes off, it verifies that all sensors are working correctly and that the alarms are in good working condition. Bump testing should be performed before each use. Make sure you are in a clean environment to perform a bump test. Bump test according to manufacturer specifications.

Follow the steps below to perform a proper bump test:

1. Make sure you have an approved calibration gas cylinder.
2. Turn the gas detector on using the normal startup procedure.
3. Attach the proper flow-per-minute regulator to the cylinder.
4. Attach the tubing to the calibration fitting for your gas detector.
5. Open the regulator to apply calibration gas to the gas detector.



Always check the expiration date

Calibration gas cylinder

The gas detector should adjust to and accurately read the concentrations of the different gases contained in the calibration gas bottle. The alarms should activate once the low alarm settings are breached.

While bump testing confirms that the sensors and alarms are working properly, it does not confirm the accuracy of the readings. Gas detectors must be properly calibrated to determine the accuracy of the readings.

Calibration

When you calibrate a gas detector, you are exposing its sensors to known concentrations of various calibration gases to make sure the detector readings will be accurate. The concentration of the calibration gases are listed on the calibration gas cylinder. Performing a calibration on a gas detector means you are comparing the readings of the gas detector to concentrations listed on the cylinder. Over time, a gas detector's sensitivity will become unbalanced. Performing a calibration gives the gas detector the opportunity to balance its sensitivity. If the sensors no longer accurately read the concentration values, i.e., give readings that do not match the gas concentrations listed on the calibration cylinder, replace the sensors.

In order to properly calibrate a gas detector, you will need calibration gas and a regulator. Check the gas detector's user manual to see which type of calibration gas you need. Make sure your calibration gas is not expired. Expired calibration gas can give false readings. Regulators are used to control the rate of gas released from the calibration gas cylinder. The Choosing the Correct Regulator table lists characteristics to keep in mind when choosing a regulator.

Many gas detectors now come with a docking or calibration station. This is used to house all the calibration equipment in one place. A calibration station provides a hands-free calibration process for the user. These stations are not universal, so

Choosing the Correct Regulator		
Characteristic	**What It Is?**	**Notes on Use**
Flow rate	Volume of fluid that passes through a given surface per cubic feet per second	- Using a regulator with the wrong flow rate will decrease calibration accuracy - Find the correct flow rate for the gas detector you are using in the user manual
Demand flow	Pulls the gas from the cylinder as needed	- Use demand flow when your gas detector has a built-in pump or when you are performing an automatic calibration using a calibration station
Fixed flow	Pulls the gas from the cylinder at a fixed rate	- Use fixed flow when your gas detector does not have a built-in pump
Material type	Brass or steel	- Use brass regulators for non-corrosive, non-reactive gases - Use stainless steel regulators for corrosive, reactive gases
Cylinder size	The cylinder size must match the regulator size	- Read the cylinder label to determine the cylinder size for the regulator - Do not guess when choosing cylinder size because the wall thickness and pressure the gas is stored under cannot be determined at a glance - Not all dimensions of cylinders will indicate the same capacity
Tubing	Collects the calibration gas and funnels it toward the air monitor	- Tubing usually comes in 3-foot lengths - Check the tubing before each use to make sure it remains defect-free - Most manufacturers recommend you change the tubing annually
Calibration adaptor/ cup/cap	Directs and traps the calibration gas	- The calibration adaptor/cup/cap forces the gas to flow over the sensors of the instrument

make sure the specific model of the gas detector is compatible with the calibration station.

All calibrations must be performed according to manufacturer instructions. The basic steps to calibrating a gas detector are:

1. Gather the materials listed in the Choosing the Correct Regulator table.
2. Turn the gas detector on using the normal startup procedure.
3. Activate the gas detector's calibration feature. This varies from gas detector to gas detector. Some require pressing and holding two buttons simultaneously where others require pressing one button for a certain period of time. Check your user manual for instructions.
4. Connect the appropriate regulator to the appropriate calibration cylinder.
5. Connect the regulator and calibration adapter using the tubing.
6. Apply the calibration gas from the calibration cylinder by opening the regulator when the detector tells you to apply span gas.
7. Allow the gas to cycle through the detector until it tells you that the calibration is successful.
8. Follow the instructions on the detector screen to set calibration dates and save the calibration.
9. Document the calibration on the log.

Any time a gas detector is dropped or handled in an unusually rough manner, perform another calibration. It is important to be familiar with your company's policies about gas detector usage and calibration requirements. Many companies use a third-party vendor to perform their calibrations. Even if the company does not want their workers to perform calibrations, workers are still required to perform bump tests before each use.

Respiratory Protection

If engineering and administrative controls cannot keep levels of H_2S below exposure limits, you must wear appropriate PPE and respiratory protection. PPE must be made from material that H_2S cannot pass through or weaken. Workers required to work in areas contaminated with H_2S concentrations over 10 ppm or their company's action level must wear supplied-air respiratory protection.

Respirators are the last line of defense between workers and inhalable hazards. Respirators protect workers from harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors when engineering and administrative controls cannot sufficiently protect them. We will go over all aspects of respiratory protection in this section so that you will have all the tools you need to protect your lungs.

Your respiratory system consists of your lungs, airways, and diaphragm. Together, these pull air in from the atmosphere, take oxygen from that air, and put it into your blood for use in almost all body functions, then you exhale what is left over. When your lungs pull oxygen from the air and put it into your bloodstream, they are vulnerable to any other inhaled particles or vapors that might harm you. Thus, inhalation is one of the four main exposure routes in which you can be exposed to hazardous substances. If engineering controls and administrative controls cannot keep you safe from inhaling contaminated air, you need to don respiratory protection.

Respirators are often needed for confined space work. Other potentially hazardous respiratory situations happen when using chlorine, and from exposure to asbestos, H_2S, or sandblasting. Welding produces metal fumes that can be toxic and hazardous if inhaled, particularly over long periods of time, so respirators may be necessary to safely perform welding operations.

Respiratory Protection Program

Your company should have a Respiratory Protection Program in place. The program will include written standard operating procedures for respiratory protection. This program is necessary because your company is responsible for identifying and assessing respiratory hazards in the workplace. Respirators must be worn in hazardous atmospheres. Hazardous atmospheres are areas where there are contaminants in excess of the PEL or TLV-TWA. Contaminants can take the form of dusts, mists, gases, vapors, or combinations of each.

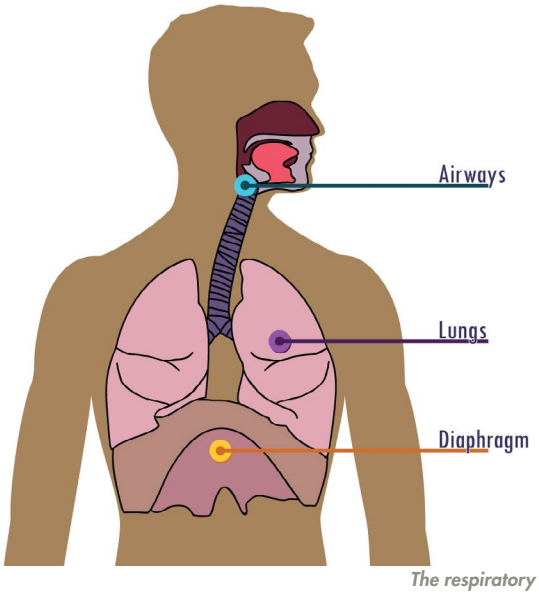
This program must include:

- Respirator selection procedures
- Worker medical evaluations for those required to use respirators
- Fit-testing procedures
- How to use respirators during routine tasks and emergency situations
- Respirator maintenance
- How to put on and take off respirators
- Respirator limits of use
- Program evaluation procedures

This program is set up to help you protect yourself. It will include steps on how to use each type of respirator your company has available, when to use which type, and what to do in an emergency. You need to know these written procedures and which respirators are available for you to use. If you ever have any questions about respirator use or cannot remember when you need to use which respirator, ask your supervisor to go over the company's Respiratory Protection Program with you.

Training

Your company must provide you with annual respiratory protection training. You must be trained in how to use a respirator. You must be taught how to use, inspect, don, doff, and check the seals of the respirator. Respiratory protection training must be comprehensive and understandable. You will need to update your training at least once a year, or more often if any of the following situations happen: workplace conditions or the type of respirator changes, you are unsure of or lack the skills to use a respirator properly, or any other situation where you may need retraining.



The respiratory system

You must be trained in proper respirator use. Workers must take protective measures to prevent respiratory PPE from being damaged. Respirators that are not kept in good condition, not used properly, or do not fit properly will not be effective in preventing contaminants from entering your respiratory system. If a respirator malfunctions, workers must immediately leave the contaminated area and report the malfunction and any changes to

their medical condition. The company you work for must also train you in:

- Both routine and emergency situational respirator use
- How to respond when the respirator malfunctions
- When a respirator is required and how improper fit, usage, or maintenance can compromise the effectiveness of the respirator
- How to properly store the respirator
- The general requirements of 29 CFR 1910.134

You must be trained in the following site-specific topics before beginning work on the site:

- Location of supplied air respirators (SARs)
- Location of spare air cylinders, if applicable
- Site-specific issues
- Situations that would require respirators
- Limitations and capabilities of positive-pressure/full-facepiece respirators
- Limitations and capabilities of supplied air respirators
- Brand/model/size of respirators available

Medical Evaluation

Your company must provide you and your coworkers with a medical evaluation to determine if you can use a respirator safely. This medical evaluation will determine if you have any medical conditions that would prevent you from using a respirator effectively. Medical conditions that can pose problems with respirators include lung, heart, and brain disease, glasses or contact lenses, back injuries, and claustrophobia.

A physician or other licensed health care provider (PLHCP) must perform the medical evaluation using the OSHA Respirator Medical Evaluation Questionnaire included in Part A of Appendix C in 29 CFR 1910.134. If the PLHCP that evaluated you believes you need a follow-up exam, your company must provide you with that exam. These medical exams must take place during working hours and at no cost to workers. You will receive a copy of the evaluation from your PLHCP. For you to use a respirator at work, your company must receive a written recommendation from the PLHCP that you can use that respirator, a statement that the PLHCP has provided you with a copy of that recommendation, any recommended respirator use restrictions, and any recommendations for follow-up exams.

You must be provided with an additional medical evaluation if:

- You report medical signs or symptoms that could affect respirator use
- A PLHCP, supervisor, or respiratory program administrator says further evaluation is needed
- Information from the respiratory protection program, including observations made during fit testing and program evaluation, indicates a need for one
- There is a change in workplace conditions that affects respirator use

Fit Testing

You must be fit tested before you can use a respirator. Fit tests determine if a respirator fits you properly. Fit tests are completed yearly and may be required more frequently if there are any changes to your facial structure that could affect the seal of a respirator, such as dental surgery or drastic weight changes. There are many common causes of leaks, including head size, face shape, wrinkles, missing dentures, and hollow temples.

For a respirator to fit, you must also meet certain requirements. You cannot have any condition that interferes with the face-to-facepiece seal or valve function. If you wear glasses or safety goggles,

PortaCounts may be used for QNFTs

they cannot interfere with the seal either. You must be clean-shaven because facial hair can interfere with the respirator seal. The most common cause of respirator seal leakage is facial hair. Follow your company's policy on facial hair. Improper fit, usage, or maintenance can compromise the protectiveness of the respirator.

There are two types of fit tests: a qualitative fit test (QLFT) and a quantitative fit test (QNFT). A QLFT passes or fails you in respirator fit based on how you react to a test agent, usually an aerosol with a strong smell. OSHA QLFT protocols include saccharin, isoamyl acetate (also known as banana oil), Bitrex, and irritant smoke. A QNFT assesses respirator fit by numerically measuring how much outside air leaks into your respirator. A PortaCount may be used to perform a QNFT. A PortaCount works by measuring the concentration of microscopic dust particles in the ambient air and then measuring the concentration of those dust particles that leak into the respirator. The ratio of these two concentrations is called the fit factor. See Appendix A of 29 CFR 1910.134 for more information about fit-test protocols.

Types of Respirators

Two major types of respirators are air-purifying respirators (APRs) and SARs. APRs filter out contaminants from the existing atmosphere. Note that APRs are not recommended for use in areas contaminated with H_2S. SARs supply clean air to the user from another source.

Worker wearing an SCBA

An SAR gives the user breathing air from an independent source, such as a cylinder or compressor. There are two types of SARs: hoseline (or airline) respirators and self-contained breathing apparatuses (SCBAs). There are three types of SCBAs: work units, rescue units, and escape packs. Escape pack SCBAs are used for short-term emergency use, and are also known as escape-only respirators, emergency-use respirators, or auxiliary SCBAs. You must know where these escape packs are located so that if there is an emergency, you know where to get appropriate respiratory protection quickly.

A hoseline (or airline) respirator has a hose attached to it that draws air from an independent source that is not carried by the user. The hoseline (or airline) respirator limits motion based on how long the hose is, and it may need to be used with a full facepiece and an auxiliary SCBA. With an SCBA, the user carries the breathing air source. This allows the user unlimited motion, but forces the user to carry the weight of the breathing air source. Cylinders supply breathing air to SCBAs, while compressors or cascade systems supply breathing air to hoseline (or airline) SARs. A cascade system is designed to provide breathing air to hoseline (or airline) respirators. Make sure each bottle has been tested before you go under air. Look for a tag.

Respirator protection systems must be NIOSH-approved. Breathing air must meet the following requirements:

- Compressed and liquid oxygen must meet US Pharmacopoeia requirements
- Compressed breathing air must meet ANSI Grade D requirements, which include:
  - An oxygen level between 19.5–23.5% O_2
  - Condensed hydrocarbon content of 5 mg/m^3 of air or less
  - Carbon monoxide content of 10 ppm or less
  - CO_2 content of 1,000 ppm or less
  - Lack of noticeable odor

Cylinders used to supply breathing air to SCBAs must:

- Be tested according to DOT requirements
- Be certified Grade D breathing air
- Not have moisture content over a dew point of -50°F at 1 atmosphere of pressure
- Be NIOSH-approved

Compressors used to supply breathing air to respirators must:

- Prevent entry of contaminated air into the air-supply system
- Reduce moisture content
- Contain a suitable filter
- Have a tag attached that states the most recent change date and the worker's signature
- Be NIOSH-approved

If you are using a SAR or an SCBA that contains compressed air, do not refill the respirator with compressed pure oxygen, or vice versa. Refill the cylinder with ANSI Grade D air at the same oxygen concentration that was in it before. Check the label to make sure you are refilling with the right air supply.

Respirator Limitations

All respirators are limited by their service life and assigned protection factor (APF). Service life refers to the length of time respiratory equipment provides adequate protection to the wearer. When you inspect your respirator, check the cylinder for adequate service life for the work you are about to perform. If the respirator has reached the end of its service life, do not use it; tag the respirator out and remove it from service.

Each type of respirator has an APF based on what it is equipped with. A respirator's APF refers to the workplace level of respiratory protection that a respirator or class of respirators is expected to provide to workers. APFs go up based on the respirator mask, facepiece, and mode. Respirators with higher APF values are more protective. Respirators that are put in positive-pressure mode have higher APF values than those in negative-pressure mode. SCBAs have the highest APFs. The Assigned Protection Factors table describes the APFs for each type of respirator.

Each respirator also has specific limitations inherent in its design. One of the most common problems is respirator seal leakage.

This respirator uses an air cylinder that meets ANSI Grade D requirements

The Respirator Type Pros and Cons chart shows the advantages and disadvantages of each type of respirator.

Each type of respirator can only be used for so long; the useful life of a respirator does not last forever.

Air Supply

The air supply in a SAR will depend on how much air is stored and how many workers are breathing from the air supply. Whether workers are using a continuous air supply from a compressor system or an air supply of multiple Grade D breathing air compressed gas cylinders, it is important to put a worker in charge of monitoring. Compressor systems are monitored for proper function and to make sure compressed gas bottles do not get completely exhausted of air.

An SCBA's air supply will vary between workers depending on lung capacity, physical ability, and their familiarity with wearing a respirator. Most SCBAs will contain around 25 to 30 minutes of air. The low air alarm is usually set at 25% of that air supply, which gives workers time to get to a safe area before they run out of air. If the low air alarm sounds, workers should immediately leave the area.

Respirators that are not in acceptable condition and cannot be repaired must be tagged and removed from service. Repairs and refurbishments are only allowed within the limitations set by the manufacturer. Any technical portion, such as valves, regulators, and alarms, must be repaired by a trained technician. Any part used for repairs must be supplied by the manufacturer and designed for the particular respirator.

Selecting Respirators for Use

The company you work for must select respirators based on the hazards within the workplace, potential worker exposure to these hazards, and user factors. Choosing the right respirator involves determining the nature of the hazardous operation and the type of respiratory hazards present. There are many different types of respiratory hazards, including:

- Physical properties
- Oxygen deficiency
- Physiological effects
- Concentration of toxic material or airborne radioactivity level
- PELs and exposure limits
- IDLH or non-IDLH
- Health concentration of toxic material

When selecting a respirator, a respirator's limitations must also be taken into account. The respirator must be NIOSH-approved. The respirator must meet the required level of worker protection based on its APF. The APF determines a respirator's maximum use concentration (MUC), or the max concentration of a hazardous substance the respirator can protect the user from. Your company must calculate the MUC for the respirators available and select respirators for workers that maintain worker exposure to the hazardous substance at or below the MUC.

In addition to considering the respiratory hazards involved in a job, those in charge of selecting respirators must consider how close the nearest area with respirable air is to the hazardous area, how long workers will need to wear respirators to get the job done, and what activities the workers are performing. Other considerations include the physical characteristics and functional capabilities of the respirator, the respirator's APF, and the extent of the hazard.

If you wish to wear a respirator when you are not required to do so, ask your supervisor for a copy of Appendix D of 29 CFR 1910.134. Your company must provide you with this appendix if you want to use a non-required respirator, and it will contain directions for use.

Assigned Protection Factors					
Type of respirator	**Quarter mask**	**Half mask**	**Full facepiece**	**Helmet/ Hood**	**Loose-fitting facepiece**
SAR					
- Demand mode		10	50		
- Continuous flow mode		50	1,000	25/1,000	25
- Pressure-demand or other positive-pressure mode		50	1,000		
SCBA					
- Demand mode		10	50	50	
- Pressure-demand or other positive-pressure mode			10,000	10,000	

Respirator Type Pros and Cons		
Respirator Type	**Hoseline/Airline SAR**	**SCBA**
Pros	- Used above IDLH with an escape pack - Used in oxygen-deficient atmosphere with escape pack - Not contaminant-specific - Low breathing resistance - Lightweight	- Offers the highest APF - Not contaminant-specific - Breathing times are relatively predictable - Can be used in oxygen-deficient, IDLH, and unknown atmospheres - Air supply is carried on the user's body - Can access remote air supplies via a hoseline connection
Cons	- Hoseline can interfere with mobility - Hoseline can never be longer than 300 ft. from the last high pressure connection - May need to be used with a full facepiece and an auxiliary SCBA	- Cost - Requires a lot of support equipment - Can have a very limited use duration under certain circumstances - Tends to be a lot heavier and bulkier than SAR - Usually requires more training than SAR

Before you use a respirator in the field, you must know the:

- Location of hoseline/airline SARs and SCBAs
- Location of spare air cylinders, if applicable
- Situations that would require respirators
- Limitations and capabilities of positive-pressure/full-facepiece respirators
- Limitations and capabilities of SARs
- Brands, models, and sizes of respirators available
- Necessary site-specific respirator information, if any

Respirator Use

Respirator Inspection

Low oxygen indicator

Inspect respirators on a regular basis. How frequently you inspect a respirator depends on what the respirator is used for. Respirators used in non-emergency situations must be inspected before each use and during cleaning. Emergency-use respirators should be inspected once a month and before and after each use. Inspect emergency escape-only respirators before bringing them into the workplace. When you inspect a respirator, check its function, tightness of connections, each component for wear and tear, and elastic parts for dry rot and pliability.

When you inspect an SCBA, make sure the air cylinders are fully charged. Check the air cylinder pressure level to make sure pressure is at 90% or higher before you use the respirator. Recharge the cylinder if its pressure falls at or below 90% capacity before you store the respirator. Also inspect the regulator and warning devices to make sure they are still functioning.

Keep records of emergency-use respirator inspections. Document the inspection date, the inspector's name and signature, inspection results, any required maintenance, and the respirator's serial number. All of this information should be available on a tag attached to the respirator or in a report filed at the facility. Your company must keep each report on file until a more recent report is received.

Respirators that fail inspection should be removed from service and thrown away or repaired. Only trained workers can repair respirators, and some repairs must be done by a manufacturer technician. If a respirator needs to be repaired, let your supervisor know so that the right person can make the repairs.

Checking the Seal

A user seal check determines if the respirator is properly sealed to your face to keep out contaminated air. There are two types of user seal checks: positive-pressure checks and negative-pressure checks. You must check the seal of your respirator each time you use it. You can use either method to check the seal, or you can follow the respirator manufacturer's instructions if they are equally effective.

To perform a positive-pressure check, close off the exhalation valve with your hand and exhale gently into the facepiece. The respirator is properly sealed if none of your exhaled breath leaks out of the seal. For

Trainer demonstrating a user seal check

most respirators, you have to remove the exhalation valve cover before closing off the exhalation valve. Carefully replace the valve after the test.

To perform a negative-pressure check, close off the inlet opening of the cartridge by covering it with the palm of your hand or by replacing the filter seal. Inhale gently so that the facepiece collapses slightly, and hold your breath for 10 seconds. Note that some cartridge inlets cannot be effectively covered with the palm of your hand. If you have one of these cartridges, cover the inlet opening of the cartridge with a thin latex or nitrile glove. If the facepiece remains slightly collapsed after holding your breath for 10 seconds and no air leaks in, the seal fits.

Maintenance, Cleaning, and Storage

You may notice vapor or gas breakthrough by either taste or smell, changes in breathing resistance, or detecting facepiece leakage. If you notice this, replace either the entire respirator or the expired canister. If you cannot replace the respirator or the expired piece, get it repaired.

To get the most out of each respirator, wash your face and the respirator facepiece with soap and water before and after each use. Respirators used by more than one worker must be cleaned and disinfected before they are worn by a different worker. Clean and disinfect emergency-use respirators and respirators used in training and fit testing after each use.

To clean a respirator, follow these steps:

1. Take the respirator apart. Disassemble the facepiece by removing speaking diaphragms, valves, hoses, and any other parts recommended for cleaning by the manufacturer.
2. Repair or throw away any defective parts.
3. Wash respirator parts in warm water with a mild detergent or with a cleaner recommended by the manufacturer. Use a stiff bristle brush (but not a wire brush) to remove any dirt.
4. Rinse respirator parts thoroughly in clean, warm, running water. Drain. Make sure all soap is removed because soap left behind can cause skin irritation and respirator degradation.
5. Hand-dry respirator parts using a clean, lint-free cloth or allow them to air dry.
6. Put the respirator back together, replacing parts when necessary.
7. Test the respirator to make sure all parts are still working.

If the soap you used did not contain a disinfecting agent, you must soak the respirator for 2 minutes using either of the following cleansers before rinsing the respirator:

- Diluted bleach (add 1 milliliter [mL] of bleach to 1 liter [L] of warm water)
- Diluted iodine (add 0.8 mL of tinctured iodine to 1 L of water)
- Other commercially available disinfectant cleansers recommended by the manufacturer

Respirators need to be stored in a safe place away from dust, sunlight, extreme temperatures, excessive moisture, and damaging chemicals to prevent facepiece and exhalation valve deformation, damage, and contamination. Emergency-use respirators must be stored in a designated area and according to manufacturer instructions.

Note that before you can work while wearing a respirator (also known as working "under air"), your company must provide you with a medical evaluation, fit test, and hands-on training that covers site-specific respirator equipment use and includes an evaluation of demonstrated proficiency.

Immediately Dangerous to Life or Health

In addition to having established exposure limits, most chemicals will have a specific IDLH concentration. Once the established IDLH concentrations are exceeded, the area is considered to be an IDLH atmosphere. IDLH atmospheres cause irreversible adverse health effects or impair an individual's ability to escape from a dangerous atmosphere. Environments with less than 19.5% O_2 are oxygen deficient and considered IDLH. Any time workers are in an area that is IDLH, they are required to wear a positive-pressure demand SCBA or a hoseline/airline SAR with a full facepiece and an escape pack. Any situation consisting of an unknown hazard must be taken as an IDLH environment.

If workers are using respirators within an IDLH environment, one or more workers are required to be on standby outside the IDLH area, and at least one worker must be trained to perform first aid and CPR. The standby workers must maintain visual, voice, or signal line communication with the workers inside the IDLH area. Standby workers may be trained and equipped to rescue workers. If they are not trained for rescue, they must notify a rescue team if rescue is needed. If they are trained rescuers, these standby workers must be equipped with pressure-demand SCBAs, or with hoseline/airline SARs and auxiliary SCBAs, and retrieval equipment. Rescuers must use the buddy system and wear SCBAs if the emergency involves interior structural firefighting. Do not respond above your level of training.

If your respirator quits working while you are in the field, tell your supervisor and go to your company's designated safe area. Either perform the repairs yourself if you have been trained to do so, or give the respirator to someone trained to perform maintenance so that the respirator can be repaired. All workers wearing SARs must use the buddy system so their buddy can help them if their respirator stops working.

Respirators for Use with Hydrogen Sulfide and Sulfur Dioxide

To work in environments contaminated with over 10 ppm of H_2S or at or over 2 ppm SO_2, ANSI and API recommend you wear one of the following forms of respiratory protection:

- A positive-pressure, full-facepiece hoseline/airline SAR and carry an escape pack
- A positive-pressure SCBA

ANSI-approved SCBAs must be provided to all contractors and visitors if they must go into H_2S-infused areas. Offshore workers must use at least two voice-transmission devices ("walkie-talkies") while wearing a respirator per 30 CFR 250.490.

Worker getting ready to enter an IDLH atmosphere

Hydrogen Sulfide in Confined Spaces

H_2S is extremely hazardous when present in confined spaces. A confined space is a space that is large enough for a worker to enter, has limited or restricted entry or exit, and is not meant to be occupied for a long amount of time. Many processes that require workers to perform tasks in confined spaces also put them at extreme risk of exposure to H_2S. Using the necessary safety measures for H_2S in confined space work will help keep you and your coworkers safe from the hazardous effects of the gas. These measures include:

- Obtaining a confined space permit that relates to H_2S exposure conditions (include the GPS location on the permit, if applicable)
- Conducting air monitoring before entering any confined space that may contain H_2S
- Ventilating the space before entering
- Conducting continuous monitoring while workers are in the confined space
- Venting or purging lines on vessels before beginning work
- Being aware of emergency rescue procedures if there is an overexposure to H_2S
- Obtaining any necessary training for procedures relating to H_2S and confined spaces

Worker entering a confined space

One Worker is Injured, One Dies from Toxic Release

Two workers were unclogging a plugged steam ejector when they lost consciousness. Materials in the pipe had decomposed and released hydrogen sulfide and CO. The air had not been monitored for hydrogen sulfide, CO, oxygen, or LEL (flammable gases) before the work started. Worker No. 1 passed out shortly after removing the line's flange. Worker No. 2 called the Emergency Response Team, telling them it looked like Worker No. 1 was having a heart attack. Worker No. 2 tried to move Worker No. 1, but passed out. The ERT arrived and performed CPR. Both workers were rushed to the hospital. Worker No. 2 recovered and was later released from the hospital. Worker No. 1 never came out of his coma and died three days later.

What went wrong?

1. The workers did not monitor the air before entering the confined space. Confined spaces must be monitored before entry and continuously monitored during work. [29 CFR 1910.146(c)(5)(ii)(F)]

Did you find anything else that may have contributed to this accident?

1. There was a potential lack of training on safe work practices.
2. The space was not ventilated.
3. There was a lack of training on permit-required space entry. 1910.134 requires that all hazards in the confined space must be identified and controlled before entry. Atmospheric testing results must be made available to the entrant before entry.
4. There was a lack of training on permit procedure. Atmospheric testing must be documented on the permit before entry and include the name of the person conducting the test.

Emergency Response

Contingency Plans

Company contingency plans give workers a step-by-step guide for dealing with emergencies. All workers must know the location of the contingency plan, assembly points (also known as muster areas), and emergency equipment. Workers must know and follow emergency shutdown procedures, rescue operations, and notification procedures. Contingency plans will have this information laid out for you.

If you work offshore, your company must turn in a copy of its contingency plan to BSEE. Onshore, it must be turned in to the appropriate state agency. Workers must know the details of their company's contingency plan to prepare for emergencies. You must learn how to respond to emergencies.

You can find your company's instructions for how to respond to H_2S emergencies in the H_2S section of its contingency plan. Each contingency plan includes but is not limited to the following:

- An immediate action plan
- Characteristics of H_2S and SO_2
- How to notify facility workers and the public
- How to request aid and take follow-up action to get the public out of the area of the exposure
- A call list of people to notify in the event of an emergency
- A map of the area, showing public areas, evacuation routes, assembly point areas, safety equipment, phones, and possibly the radius of exposure
- Training requirements and drill schedule
- Shelter-in-place procedure (don SCBA, then get to the nearest safe haven)
- List of names and phone numbers of residents and government officials within the area of exposure
- Instructions for advanced briefing of the public within the area of exposure
- Emergency operating procedures for each job title
- How to contain and eliminate the emergency
- Emergency medical services available, including current names and phone numbers (prior contact should be made with designated medical facilities)
- Dispersion models, if applicable

Dispersion Models

Your company's contingency plan may also include an H_2S release dispersion model. Dispersion models should be considered when H_2S concentrations and volumes have the potential to affect workers or the public to the extent that an emergency condition may result from accidental release.

Dispersion models are available for predicting conditions that may result from a release of H_2S. Computer-generated H_2S dispersion models are acceptable for use in emergency planning. These models can be used to calculate vapor cloud travel and exposure concentrations over specific time periods. The effectiveness of dispersion modeling increases with the accuracy of the H_2S data input into the model.

Immediate Action Plans

You also need to know what to do immediately during an emergency. The immediate action plan for H_2S includes the following steps:

1. Stop breathing and purge and then don your emergency-use respirator or escape pack, if available.
2. If an emergency-use respirator or escape pack is not available, stop breathing and move away from the source of H_2S or SO_2 and get out of the affected area, making sure to move crosswind (at a right angle) and then upwind of the source.
3. Alert other affected workers.
4. Go to your company's emergency assembly point.
5. Account for all workers.
6. Help workers in distress if trained to do so and you have the appropriate PPE.

Refer to the DOT's Emergency Response Guidebook (ERG) Guide 117 for more information about H_2S emergency procedures.

Rescue

An H_2S emergency may leave a victim behind. Only rescue a victim if you have been trained to do so because you could easily add to the victim count if not. You must first protect yourself before you can rescue someone else. Companies must train workers in site-specific rescue techniques. If you are trained

Know where your company's assembly point is

and are going to perform a rescue, tell your coworkers first so they know what is going on. When rescuing someone, always have backup. Take another trained rescuer with you.

The following is a typical rescue procedure for H_2S:

1. If properly trained in rescue, don all necessary PPE.
2. With another trained rescuer, go to the affected person.
3. Move the affected person away from the source of hazardous exposure.
4. If the affected person has been overcome, notify the appropriate emergency medical services as quickly as possible.
5. Start your company's established emergency rescue procedures.
6. Remember to be aware of where rescue equipment is kept.

According to the ERG Guide 117, you should do the following to perform a rescue:

1. Move the victim to fresh air.
2. Call 911 or EMS.
3. If the victim is not breathing, position yourself on the upwind side and give rescue breaths using a one-way valve. Be careful not to inhale the exhaled breath of the victim, as it may contain enough H_2S to make you a victim too. Use a bag valve mask if available.
4. Remove and isolate contaminated clothing and shoes.
5. If the victim made contact with H_2S, immediately flush skin or eyes with running water for at least 20 minutes.
6. If liquefied H_2S got on the victim's skin, thaw frostbitten parts with lukewarm water.
7. If the victim was burned, immediately cool affected skin for as long as possible with cold water.
8. Remember that health effects of H_2S exposure may be delayed. Make sure medical personnel are aware of the hazardous materials involved so they can protect themselves.
9. Send the Safety Data Sheet (SDS) the hospital with the victim.

First Aid

For a victim to survive, EMS must be activated as quickly as possible. In addition to quick response, each worker must know rescue techniques and how to give first aid to victims of H_2S and SO_2. Workers must be trained in rescue breathing, CPR, and resuscitation equipment. Your company should use drills to let you practice these techniques. For first aid and rescue, you need to know where each of these items are: first aid kits, resuscitators, and stretchers.

All workers must be trained in how to use fresh-air breathing equipment and resuscitation equipment. Practice drills should be frequent and comprehensive.

To perform basic first aid for a victim of H_2S, you must first identify the type of exposure that has occurred. Take a look at the first aid procedures in the First Aid for Victims of Hydrogen Sulfide table.

Bag valve mask

GUIDE 117 GASES - TOXIC - FLAMMABLE (EXTREME HAZARD) ERG2008

POTENTIAL HAZARDS

HEALTH

- **TOXIC; Extremely Hazardous.**
- May be fatal if inhaled or absorbed through skin.
- Initial odor may be irritating or foul and may deaden your sense of smell.
- Contact with gas or liquefied gas may cause burns, severe injury and/or frostbite.
- Fire will produce irritating, corrosive and/or toxic gases.
- Runoff from fire control may cause pollution.

FIRE OR EXPLOSION

- These materials are extremely flammable.
- May form explosive mixtures with air.
- May be ignited by heat, sparks or flames.
- Vapors from liquefied gas are initially heavier than air and spread along ground.
- Vapors may travel to source of ignition and flash back.
- Runoff may create fire or explosion hazard.
- Cylinders exposed to fire may vent and release toxic and flammable gas through pressure relief devices.
- Containers may explode when heated.
- Ruptured cylinders may rocket.

PUBLIC SAFETY

- **CALL Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- As an immediate precautionary measure, isolate spill or leak area for at least 100 meters (330 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind.
- Many gases are heavier than air and will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Keep out of low areas.
- Ventilate closed spaces before entering.

PROTECTIVE CLOTHING

- Wear positive pressure self-contained breathing apparatus (SCBA).
- Wear chemical protective clothing that is specifically recommended by the manufacturer. It may provide little or no thermal protection.
- Structural firefighters' protective clothing provides limited protection in fire situations ONLY; it is not effective in spill situations where direct contact with the substance is possible.

EVACUATION

Spill

- See Table 1 - Initial Isolation and Protective Action Distances.

Fire

- If tank, rail car or tank truck is involved in a fire, ISOLATE for 1600 meters (1 mile) in all directions; also, consider initial evacuation for 1600 meters (1 mile) in all directions.

ERG2008 GASES - TOXIC - FLAMMABLE (EXTREME HAZARD) GUIDE 117

EMERGENCY RESPONSE

FIRE

- **DO NOT EXTINGUISH A LEAKING GAS FIRE UNLESS LEAK CAN BE STOPPED.**

Small Fire

- Dry chemical, CO_2, water spray or regular foam.

Large Fire

- Water spray, fog or regular foam.
- Move containers from fire area if you can do it without risk.
- Damaged cylinders should be handled only by specialists.

Fire involving Tanks

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Do not direct water at source of leak or safety devices; icing may occur.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.

SPILL OR LEAK

- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Fully encapsulating, vapor protective clothing should be worn for spills and leaks with no fire. • Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material. • Do not direct water at spill or source of leak.
- If possible, turn leaking containers so that gas escapes rather than liquid.
- Prevent entry into waterways, sewers, basements or confined areas.
- Isolate area until gas has dispersed.
- Consider igniting spill or leak to eliminate toxic gas concerns.

FIRST AID

- Move victim to fresh air. • Call 911 or emergency medical service.
- Give artificial respiration if victim is not breathing.
- **Do not use mouth-to-mouth method if victim ingested or inhaled the substance; give artificial respiration with the aid of a pocket mask equipped with a one-way valve or other proper respiratory medical device.**
- Administer oxygen if breathing is difficult.
- Remove and isolate contaminated clothing and shoes.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- In case of contact with liquefied gas, thaw frosted parts with lukewarm water.
- In case of burns, immediately cool affected skin for as long as possible with cold water. Do not remove clothing if adhering to skin.
- Keep victim warm and quiet. • Keep victim under observation.
- Effects of contact or inhalation may be delayed.
- Ensure that medical personnel are aware of the material(s) involved and take precautions to protect themselves.

Emergency Response Guidebook Guide 117

First Aid for Victims of Hydrogen Sulfide	
Inhalation exposure	- Get medical attention immediately - If a person breathes in large amounts of H_2S, move that person to fresh air immediately, if you are trained to rescue. - If the victim is not breathing, perform rescue breathing, preferably with a one-way valve. - Keep the affected person warm and at rest.
Skin exposure	- If liquid H_2S gets on the skin, immediately flush the contaminated skin with water. - If liquid H_2S goes through your clothes, remove the clothes immediately and flush the skin with water.
Eye exposure	- Flush your eyes immediately with large amounts of water, lifting the upper and lower lids occasionally. - If your eyes still feel irritated after washing, get medical attention.

Hydrogen Sulfide Overexposure Kills Three Workers

A worker entered a dry well confined space. As he descended an 18-ft. ladder, he was overcome by hydrogen sulfide. A second worker tried to rescue the first worker, but was also overcome by the toxic gas. A third worker entered the confined space to try to rescue the first two workers and suffocated. All three workers died at the scene.

What went wrong?

1. The second worker did not recognize the signs of hydrogen sulfide when his coworker was overcome. [ANSI Z390.1 3.3.2 and 3.3.3]

2. The second and third workers rushed to rescue their fallen coworker, but were overcome themselves because they were not prepared. They did not have appropriate rescue equipment or respiratory protection, and neither worker notified EMS. [API RP 55 Section 6.5 and 6.6]

Did you find anything else that may have contributed to this accident?

1. There was a potential lack of training on safe work practices.

2. The air was not monitored before the first worker entered the confined space.

3. The space was not ventilated.

4. A winch system was not used to act as protection against a fall and was not in place for rescue.

5. There was a lack of training on permit-required confined space entry requirements of 1910.134 (communication, rescue, and conditions of the permit).

6. There was a lack of supervision during the permit space entry.

7. There was a lack of appropriate PPE for entrant and rescuer, i.e. respirators and personal monitors.

8. There was inadequate rescue procedure implementation and training. (Could the second worker or third worker have manually retrieved the incapacitated first worker trapped up an 18 ft. vertical ladder?) This is evident because rescue equipment was not provided and the workers were not trained in its use.

Post-exposure Medical Evaluation

Victims of H_2S inhalation are in danger of developing medical complications for some time after rescue. Once the immediate H_2S emergency is under control, victims should be transported to a health care facility to receive professional medical attention and remain under observation until released by a licensed health care professional. Some delayed physiological effects, which may appear at a later date, include pulmonary edema, dizziness, photophobia, and nausea, to name a few. In some severe exposures, hyperbaric oxygen therapy may be recommended by the attending physicians. Individuals overcome by H_2S who have recovered and wish to return to work must receive medical clearance before they can return to the workplace.

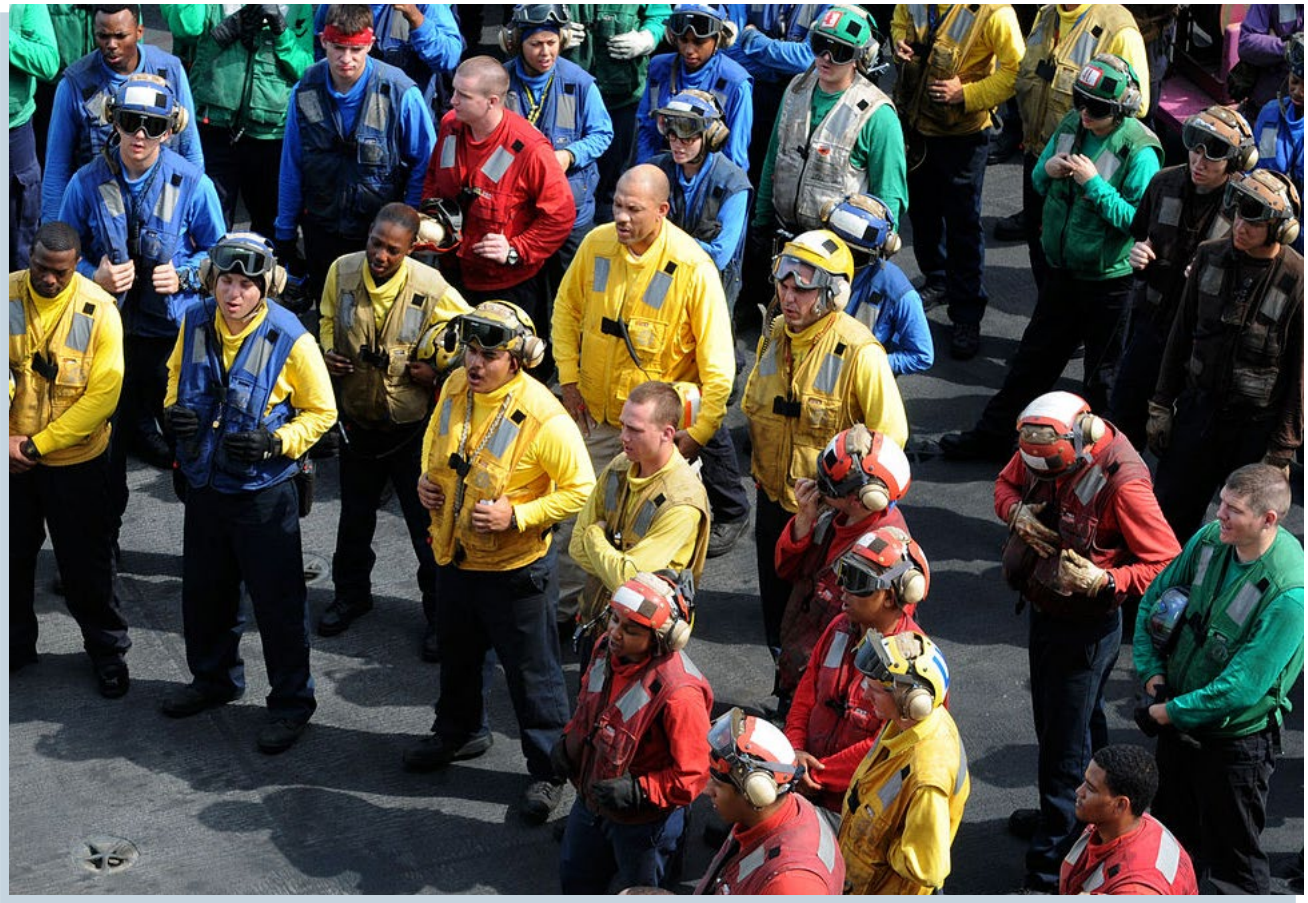
Workers using the buddy system to don PPE

Emerging Technology

Workers should be trained on emerging technologies in the areas of respiratory protection equipment, portable and fixed detection and monitoring devices, and the development of chemical treatment technologies that could potentially reduce the presence of H_2S. H_2S training instructors and supervisors should remain aware of advances in technology.

Protect Yourself

H_2S is an invisible hazard. To increase safety in oil and gas settings where H_2S is present or may be present, there must be guidelines for safe operations. In order to work safely in potential areas of exposure, you must be aware of your role, understand the controls that are in place, and follow any policies and procedures required by the operator or your company. You must receive training on planning, selecting equipment and materials, and operation and emergency procedures. To increase operational safety, H_2S courses may be required for those workers who have an increased potential to be exposed to H_2S. If you are working in an area where H_2S is present, you may be required to attend another H_2S-specific course. Hazards can be fatal if they are not fully understood or controls are not fully complied with. Commitment to H_2S safety is essential for the well-being of everyone on the worksite.



Glossary

Acute toxicity – adverse health effects that happen after a single exposure to a substance, or multiple exposures within a short period of time

Administrative controls – work practices used to reduce worker exposure that cannot be controlled using engineering controls

Air monitoring – assessing what hazards are in the air and how concentrated they are

Air-purifying respirator (APR) – has an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing air through an air purifier

Alarm system – provides an early warning signal; required at your workplace and should be seen and heard throughout the workplace

Assigned protection factor (APF) – a number that stands for the level of protection a properly functioning respirator would be expected to provide to properly fitted and trained users

Audible alarms – devices that can be distinguished above and apart from the normal sound level in the workplace

Auto-ignition temperature – the lowest temperature at which a substance will spontaneously ignite

Bag valve mask – a type of oxygen resuscitation equipment used to give breathing air to fallen workers in an emergency

Breathing zone – the area just in front of the face and shoulders; a hemisphere with a 6-9 in. radius that centers on your nose

Buddy system – a safe work practice that pairs workers together so that if one buddy needs helps, their buddy can assist them or call for help

Bump test – exposing a gas detector to a defined concentration of gases to make sure its alarms and sensors are working properly

Burning and flaring – controlled burning of a high vapor pressure liquid or compressed gas in order to reduce or control the pressure and/or dispose of the of the product

Calibration – exposing gas detector sensors to known concentrations of different calibration gases to make sure a gas detector's readings are accurate

Cascade system – a system of breathing air cylinders designed to provide breathing air to hoseline respirators

Chronic toxicity – adverse effects that happen after continuous or repeated exposure to a toxic substance

Compressor – a machine that is part of the system used to provide breathing air to a hoseline supplied-air respirator

Confined space – a space that is large enough for a worker to enter, has limited or restricted entry or exit, and is not meant to be occupied for a long amount of time

Contingency plan – a company document that gives workers a step-by-step guide for dealing with emergencies

Corrosion – metal degradation caused by hazardous chemicals

Crosswind – moving at a right angle to the current wind direction

Density – a measurement of how heavy a substance is when compared to normal air at an equal temperature and atmospheric pressure

Dispersion model – a model used for predicting conditions that can happen as a result of a release of hydrogen sulfide; can be included as part of a company's contingency plan

Downwind – working where the wind could blow hydrogen sulfide in your direction

Emergency Response Guidebook – details how emergency responders should act during the initial phase of a dangerous goods or hazardous materials transportation incident; issued by the United States Department of Transportation

Engineering controls – reduce sources of exposure through jobsite design and modification

Escape pack – a self-contained breathing apparatus respirator used for short-term emergency use; also known as an emergency-use respirators, escape-only respirator, or an auxiliary self-contained breathing apparatus

Fit test – a test that makes sure a respirator is completely sealed with no leaks that would let contaminants in

Fixed monitor – a device that continuously monitors hydrogen sulfide concentrations in a specific location

Hazardous atmosphere – areas where there are contaminants in excess of the permissible exposure limit or threshold limit value-time-weighted average

Hoseline respirator – a supplied-air respirator that gets breathing air from a cascade system or compressor from an attached hose; also known as an airline respirator

Hoseline respirator – a supplied-air respirator with a hose attached to it that draws air up from an independent source that is not carried by the user; also known as an airline respirator

Hydrogen sulfide (H_2S) – toxic gas that is colorless and collects in low-lying areas and confined spaces

Immediate action plan – a plan that describes what to do as soon as you are aware of an emergency situation

Immediately dangerous to life or health (IDLH) – an environment that causes negative health effects that cannot be reversed and reduces your ability to escape from a dangerous atmosphere

Job safety analysis (JSA) – formal review of a jobsite for hazards that is completed before work begins

Kick – also known as a burp; an entry of water, gas, oil, or other formation fluid into the wellbore during drilling or work over that occurs because the pressure exerted by the column of fluid in the wellbore is not great enough to overcome the pressure exerted by the fluids in the formation drilled

Maximum use concentration (MUC) – the maximum atmospheric concentration of a hazardous substance a worker can be expected to be protected from when wearing a respirator that is determined using a respirator's assigned protection factor and a hazardous substance's exposure limit

Metal sulfide – a product formed by a reaction between hydrogen sulfide and a metal, such as iron or steel, which could auto-ignite and burn when exposed to air

Naturally occurring radioactive material (NORM) – made up of materials enriched with radioactive elements found in the environment

Negative-pressure seal check – a way to check a respirator's integrity by closing off the inlet opening to see if any air leaks into the respirator

Oxidizer – a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, causing fire either by itself or through the release of oxygen or other gases

Oxygen deficiency – when there is less than 19.5% oxygen in the air

Oxygen resuscitation equipment – used to give breathing air to fallen workers in an emergency

Parts per million (ppm) – a measurement that means parts of a vapor or gas per million parts of air, by volume

Personal monitor – a device workers wear within the breathing zone that measures hydrogen sulfide concentrations in the surrounding air

Portable monitors – also known as gas detectors; a device designed to be placed between a worker and the source of hydrogen sulfide or in a confined space; used to measure the amount of hydrogen sulfide in the atmosphere

Positive-pressure seal check – a way to check a respirator's integrity by closing off the exhalation valve to see if any air leaks out of the respirator

Qualitative fit test (QLFT) – an exam that relies on your response to a test agent to determine if a respirator is completely sealed

Quantitative fit test (QNFT) – an exam that measures how much a respirator leaks

Regulator – a device used to control the rate of gas released from the calibration gas cylinder during portable monitor (gas detector) calibration

Respirator – a device that covers your mouth and nose and is designed to improve the air your lungs breathe in

Safety data sheet (SDS) – gives detailed information about the hazards of a specific material and how to control those hazards

Self-contained breathing apparatus (SCBA) – a supplied-air respirator where the breathing air source is designed to be carried by the user

Service life – how long respiratory equipment provides workers with enough protection

Shelter-in-place – staying indoors until an emergency is over rather than trying to evacuate

Soluble – a substance's ability to dissolve in other liquids, particularly water

Sour – term commonly used to refer to environments or fluids (such as crude oil) that contain hydrogen sulfide

Sour environments – fluids that contain water and hydrogen sulfide (Core 2015 glossary)

Spontaneous – describes something that happens without warning

Standby worker – A worker required to be outside an immediately dangerous to life or health area while workers are inside who must maintain communication with the workers inside and may be trained and equipped to rescue workers inside or be available to notify a rescue team if needed

Stop work authority (SWA) – your right to stop work when you or your coworkers are at risk because of the way a job is being done

Sulfide stress cracking – cracks in susceptible metals caused by corrosive hydrogen sulfide

Sulfur dioxide (SO_2) – very irritating, toxic, and colorless gas that has a strong, nasty odor

Supplied-air respirator (SAR) – type of respirator that supplies clean air to the user from some other source

Upwind – working in an area away from the way the wind is blowing the source of hydrogen sulfide; moving opposite the direction the wind is blowing

Ventilation – a method of controlling the environment with air flow; an engineering control used to improve or maintain the quality of air in a work environment

Visual alarms – the use of steady, flashing, or strobe lights to alert workers to an emergency situation in areas with high noise levels

Wind sock – a device used to check which way the wind is blowing

Acronyms and Abbreviations

ACC	Acceptable ceiling concentration
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
APF	Assigned protection factor
API	American Petroleum Institute
APR	Air-purifying respirator
BSEE	Bureau of Safety and Environmental Enforcement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2	Carbon dioxide
CPR	Cardiopulmonary resuscitation
DOT	Department of Transportation
EMS	Emergency medical services
EPA	Environmental Protection Agency
ERG	Emergency Response Guidebook
g/L	Grams per liter
GHS	Globally Harmonized System
H_2S	Hydrogen sulfide
IDLH	Immediately dangerous to life or health

ISA	Instrument Society of America
JSA	Job safety analysis
L	Liter
LEL	Lower explosive limit
mL	Milliliter
mmHg	Millimeters of mercury
MUC	Maximum use concentration
NFPA	National Fire Protection Agency
NIOSH	National Institute for Occupational Safety and Health
NORM	Naturally occurring radioactive material
O_2	Oxygen
OEL	Occupational exposure Limit
OSHA	Occupational Safety and Health Administration
PAPR	Powered air-purifying respirator
PEL	Permissible exposure limit
PLHCP	Physician or other licensed health care provider
PPE	Personal protective equipment
ppm	Parts per million
QLFT	Qualitative fit test
QNFT	Quantitative fit test
REL	Recommended exposure limit
RP	Recommended practice
RQ	Reportable quantity
SAR	Supplied-air respirator
SARA	Superfund Amendments and Reauthorization Act
SCBA	Self-contained breathing apparatus
SDS	Safety Data Sheet
SO_2	Sulfur dioxide
STEL	Short-term exposure limit
TLV	Threshold limit value
TWA	Time-weighted average
UN ID	United Nations Identification Number
USCG	United States Coast Guard
WHMIS	Workplace Hazardous Materials Information System